PRODUCTIVITY OF MUSTARD IN RELATION TO MINERAL NUTRITION AND PYRIDOXINE APPLICATION

ABSTRACT

THESIS SUBMITTED TO
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IN

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Abstract of the thesis, submitted to the Aligarh Muslim University, Aligarh, India, for the degree of Doctor of Philosophy in BOTANY 1988.

Four field trials on mustard (Brassica juncea Czern. & Coss.) were undertaken during 'rabi' season at the Farm of the Aligarh Muslim University, Aligarh (India) from 1983 to 86.

Experiment 1 (1983-84) was conducted according to factorial randomised block design, to study the comparative performance of ten mustard varieties, namely, KRV-47, Pusa Bold, PR-18, RK-1467, RK-8201, RK-8202, RK-8203, RK-8301, RK-8302 and Varuna, grown under two levels each of nitrogen (60 and 90 kg N/ha) and phosphorus (20 and 30 kg P/ha) in four combinations ($N_{60}P_{20}$, $N_{60}P_{30}$, $N_{90}P_{20}$, $N_{90}P_{30}$). Growth parameters were studied at 50, 70 and 90d after sowing; NAR was calculated for the periods 50-70d and 70-90d; yield and quality parameters were studied at harvest. Among fertiliser treatment $N_{60}P_{30}$ proved best for growth characteristics; $N_{60}P_{20}$ for NAR, yield and quality characteristics, Varuna excelled other varieties for all growth parameters, NAR, yield and quality parameters. Interaction $N_{90}P_{30}$ X Varuna, in general, proved best for most of the parameters.

Experiment 2 (1984-85) was conducted, according to simple randomised block design, to study the effect of soaking of mustard var. Varuna seeds in 0 (water-soaked), 0.05, 0.10 and 0.20% aqueous pyridoxine hydrochloride solution for 4h on growth characteristics, NAR, yield and quality characteristics at the same stages as in Experiment 1. In this and other experiments root length and leaf NPK content were also estimated at 50, 70 and 90d of growth. A uniform basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly. 0.05% seed treatment gave optimum value for all growth parameters, NAR, leaf NPK content, yield and quality characteristics. However, oil content of the seeds was optimum in 0.10% seed treatment.

Experiment 3 (1985-86) was conducted, according to factorial randomised block design, to study the effect of pre-sowing seed treatment for 4h with 0.0125, 0.025, 0.05 and 0.10% pyridoxine solution and three selected combinations of nitrogen and phosphorus ($N_{60}P_{20}$, N_{90} P_{30}, $N_{60+30}P_{30}$) on growth, NAR, leaf NPK, yield and quality characteristics of mustard var. Varuna. In addition to seed treatments, unsoaked and water-soaked controls were included for comparison. The first two fertiliser combinations ($N_{60}P_{20}$, $N_{90}P_{30}$) consisted of nitrogen at the rate of 60 and 90 kg N/ha and phosphorus at 20 and 30 kg P/ha respectively applied to the soil at the time of sowing. In the third combination ($N_{60+30}P_{30}$), in addition to nitrogen and phosphorus added to the soil at the rate of 60 kg N and 30 kg P/ha respectively, top-dressing of 30 kg N/ha was also done at 70d after sowing. Seed treatment with 0.025% pyridoxine solution proved best for all growth characteristics, NAR, leaf NPK content, yield and quality characteristics. However, hectolitre weight was maximum in 0.0125% seed treatment. Fertiliser treatment ($N_{60}P_{20}$) gave maximum value for most of the parameters studied. Regarding interaction effect, 0.025 X $N_{90}P_{30}$, 0.025 X $N_{60}P_{20}$ and 0.0125 X $N_{60}P_{20}$ (being at par) proved best for most of the characteristics studied.

Experiment 4 (1985-86) was conducted according to factorial randomised block design with the aim to study the effect of pre-sowing seed treatment for 4h with 0.0125, 0.025, 0.05 and 0.10% pyridoxine solution on growth, NAR leaf NPK content, yield and quality characteristics of three varieties of mustard, namely, PR-18, RK-8203 and Varuna. Unsoaked and water-soaked controls were taken for comparison. Seed treatment, 0.0125% enhanced various growth parameters, NAR, leaf NPK content, yield and quality parameters. The performance of varieties were in the order: Varuna > RK-8203 > PR-18 for most of the characteristics. Interaction 0.0125 X Varuna and 0.05 X RK-8203 (being at par) manifested, in general, maximum effect.

In the present study, values of correlation coefficients in Experiment 4 were also calculated. These findings indicate that vegetative and reproductive growth contributes cumulatively to seed yield. Degree of strong correlation ($p < 0.01$) followed the order: PR-18 > RK-8203 > Varuna.

To sum up, it was concluded that pre-sowing seed treatment with pyridoxine reduces the requirement of fertiliser in high dose requiring variety without affecting seed and oil yield as well as oil quality. Further, pyridoxine content in seeds of mustard varieties may be taken as criterion to ascertain the positive response of variety, and its exogenous application may be used for improving the performance of a variety by pre-sowing seed treatment.

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C E R T I F I C A T E

This is to certify that the thesis entitled "Productivity of Mustard in Relation to Mineral Nutrition and Pyridoxine Application", submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Botany, is a faithful record of the bonafide research work carried out at the Aligarh Muslim University, Aligarh, by Mr. Nafees Ahmad Khan under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

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C O N T E N T S

CHAPTER - 1

INTRODUCTION

INTRODUCTION

Man's conscious interest in plants goes back to the era before recorded history. Eversince he began living in social groups, he started to cultivate plants (and breed domestic animals) for his livelihood. These not only fulfilled his food requirements but also proved useful in many other ways. With the rapid progress in industrialisation in recent years, these natural resources have become limited due to the ever-increasing demands of the people. Consequently, to cope with this startling situation, cultivation of crops has become a skilled occupation.

Among the major crops, oilseeds occupy a prominent position in overall world food production. It accounts for about 10% of cultivated land. Presently, the area under oilseed cultivation in the world exceeds 100 million hectares which is nearly 12% of the area under grain crops and equal to the area under legume cultivation. Besides being used as an essential part in daily human diet, it forms the mainstay of several industries like soap, paint, varnish, hair oil, lubricant and grease. Oilcake, a by-product, is used as cattle feed and also in the form of organic manure. Among major oilseeds, mustard occupies one-fifth area of the cultivated land in India. Uttar Pradesh (U.P.) dominates in its cultivation, accounting for about 60% of the all India acreage under this crop.

The production of oilseeds during the last two decades has failed to keep pace with increasing domestic and industrial demands. Inspite of the large area under oilseed cultivation, the low average yield has resulted in a perpetual shortage of this essential commodity. The total supply of edible oil, including imports, stands at 4.77 million tonnes which makes its per capita availability 6.88 kg/annum, whereas according to the Indian Council of Medical Research, the per capita nutritional requirement of oil is 14 kg/annum. The country would require an additional 5.0 million tonnes of edible oils to achieve this standard.

The large gap between supply and demand has necessitated import of edible oils every year on a large scale. However, import cannot be increased beyond a certain limit as it would not only affect the balance of payments but also harm the forces of production within the country. Moreover, the gap between supply and demand is increasing at an alarming speed due to the so-called "population explosion". In fact, the situation has become so acute that the Prime Minister of India has created a new Secretariat under his personal guidance for augmenting oilseed production and productivity in the country.

The low production is due to various constraints, including cultivation of 90% oilseed crops under rainfed conditions where the yield is as low as 60% of irrigated areas. The low production is also due to the lack of methodology necessary for exploiting fully the genetic potential of the newly evolved high yielding varieties. These varieties require large amounts of synthetic fertiliser which an average farmer cannot afford to apply due to his poor economic condition.

Crop yield is controlled by an interaction between the genetic potentialities of the crop and the environment in which it grows. Any mismatch between the genotype and the environment results in low output. The genotype can be managed in such a way so as to enable the plant to explore the soil environment fully. This task can be achieved by proliferating the root system through exogenous supply of growth promoting substances. Among various growth promoting substances, pyridoxine (vitamin B_6) plays a pivotal role in enhancing root growth. It has been found that pyridoxine increases root growth (Bonner and Bonner, 1948; Åberg, 1961; Afridi et al. 1979; Khan and Ansari, 1984) and uptake of nutrients (Ovcharov and Kulieva, 1968; Gopala Rao and Raghava Reddy, 1985). Moreover, it helps in maintaining proper sink-source relationship and in partitioning of metabolites. Pyridoxine has also been found to affect the growth and yield performance of several crops when applied to seeds (Sinkovics, 1970).

Researches undertaken at Aligarh have shown that when seeds of cereals and legumes, treated with aqueous dilute solution of pyridoxine sown in the field, showed enhanced proliferation of roots at seedling stage. These plants have much better chance of establishing themselves and to explore more soil specially in terms of nutrients and water. This is reflected in better growth and increased photosynthetic area leading ultimately to higher yield (Ahmad, 1975; Afridi et al. 1979; Ahmad et al. 1981, 1982; Ashfaq et al. 1983; Khan and Ansari, 1984; Samiullah et al., 1985 a; Ansari, 1986; Ansari and Khan, 1986). However, these studies did not include oilseeds. Also, the effect of interaction of soaking of seeds in pyridoxine solution and fertiliser as well as performance of various varieties under the influence of seed treatment has not been studied. With this view in mind, four field experiments were conducted on mustard on the following lines:

(1) Screening the available high yielding mustard varieties to select the best locally adapted variety on the one hand and to determine the next suitable combination of N and P on the other for their optimum performance.

(2) Studying the effect of pre-sowing seed treatment with pyridoxine on the performance of the mustard variety selected in the first trial.

(3) Determining the effect of soaking of seeds in dilute pyridoxine solution on fertiliser economy.

(4) Studying the effect of soaking of seeds in pyridoxine on the improvement in performance of various varieties of mustard.

CHAPTER - 2

REVIEW OF LITERATURE

C O N T E N T S

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Eversince his existence, man must have observed many phenomena in the surroundings due to his natural curiosity. Later, some of these would have been exploited for his welfare. The commencement of agriculture seems to be such an outcome of his experience on plants and their relationship with the environment. He must have observed that seeds of plants, when buried in soil, produce full-fledged crop. This phenomenon encouraged him to cultivate the land. As time passed and the population increased, the only alternative left with him was to increase the agricultural produce with his limited available resources. Since then, gradually several steps have been taken to increase the productivity and quality of the crop. Considerable success has been achieved in understanding the importance of nutrients, particularly NPK, in increasing the yield and quality of crop. In recent years, attention has been focussed to develop new vistas in this direction. Among them, chemical and physical pre-sowing treatment of seeds of established high yielding varieties grown with optimum NPK has shown considerable promise. At Aligarh, seed treatment of barley, lentil and mungbean with pyridoxine (vitamin B_6) has proved effective as well as economical for the purpose (Ahmad, 1975; Ansari, 1986). However, detailed study of the effect of this (or other) vitamin on the productivity of oilseeds, particularly rapeseed mustard has not been made so far. Keeping this in view, the present investigation was undertaken as mentioned earlier (p. 4). A brief review of the available literature is given in the following pages.

2.1 Mineral nutrition

The importance of plant nutrition is known from the time of the Greek civilisation. The history of research on plant nutrition, however, dates back to 1656 when Glauber obtained saltpetre from cattle manure and found that it had great stimulating effect on plant growth. However, credit goes to de saussure who, for the first time in 1804, emphasised a close relationship between the minerals found in the soil and the plants that thrived on it. Later, Boussingault in France, Liebig in Germany and Lawes and Gilbert in England elaborated other aspects of mineral nutrition (Russell, 1950).

By using water culture techniques, Sachs and Knop in 1860 were able to demonstrate independently the essentiality of ten elements, namely carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, sulphur, magnesium and iron. These elements (except iron) are required in large quantities and they have been named macro-nutrients. The importance of six more elements which are required in very small amounts and are known as micro-nutrients was established in the present century. These elements together with iron from the first list, include boron, chlorine, copper, manganese, molybdenum and zinc (Hewitt, 1963).

2.1.1 Role of NPK in plant metabolism

Nutrients perform many important functions in plants. Among macro-nutrients, much work has been done on nitrogen phosphorus and potassium because they play role of paramount importance in the life of plants and are removed by them in large quantities.

2.1.1.1 Nitrogen

In addition to its absorption generally in the form of NO_3^-, nitrogen is also taken up as NH_4^+. Once inside the plant, nitrogen is reduced and incorporated into diverse organic compounds (Bandurski, 1965; Beevers and Hageman, 1969). It is an integral part of a large number of essential organic compounds, including amino acids, proteins, co-enzymes, porphyrins, purines, pyrimidines, chlorophyll, some vitamins and growth hormones. Porphyrin structure is found in such metabolically important compounds as chlorophyll and cytochromes, essential in photosynthesis and respiration. Purines and pyrimidines are the constituents of ribonucleic acid and deoxyribonucleic acid, required for protein synthesis and transfer of genetic information (Devlin and Witham, 1986).

The deficiency of nitrogen results in stunted growth and yellowing of leaves on account of loss of chlorophyll.

This yellowing is first observed in the older leaves as nitrogen is readily translocated from older leaves to younger leaves. Nitrogen fertilisation increases the cation exchange capacity of plant roots and thus makes them more efficient in absorbing other nutrient ions (Tamhane et al., 1970). Plants supplied with excessive nitrogen are usually dark green in colour, abound in foliage, usually have feebly developed root system and low root/shoot ratio. Excessive application of nitrogen also reduces flowering and seed formation in several crops and delays maturity (Curtis and Clark, 1950; Black, 1973).

2.1.1.2 Phosphorus

Phosphorus is absorbed by roots both as monovalent ($H_2PO_4^-$) and divalent (HPO_4^{--}) anions. The quantity of either ion present in the soil, is dependent upon the pH of the soil solution. The lower pH favours $H_2PO_4^-$ and higher pH, HPO_4^- ion (Devlin and Witham, 1986).

Phosphorus is a basic constituent of nucleic acids, phospholipids, phytin, adenosine and other triphosphates, pyridoxal phosphate and thiamine pyrophosphate, phosphorylated sugars and their intermediary metabolic products found in the various metabolic pathways of respiration and photosynthesis. It is also an integral part of other important molecules, like nucleoproteins, purines, pyrmidines and flavin nucleotides (Nason and McElroy, 1963). As a constituent of nucleoproteins, it is concerned with cell division and transfer of hereditary characters through chromosomes, As constituent of phospholipids, e.g., lecithin, phosphorus is believed to be present in the cell membrane (Devlin and Witham, 1986). Hydrogen ion (H^+) carriers, nicotinamide adenine dinucleotide and nicotinamide ademine dinucleotide phosphate play a pivotal role in Kreb's cycle, glycolysis and pentose cycle. Pyridoxal phosphate is required for transamination system (Green et al., 1945; Lichstein et al., 1945) and thiamine pyrophosphate is one among five essential cofactors required for the formation of acetyl coenzyme A (Korkes et al., 1951, 1952; Gunsalus, 1954). Phosphate participates directly in the photochemical events of photosynthesis through orthophosphate and nicotinamide adenine dinucleotide phosphate, required for the production of "assimilatory power" (Devlin and Witham, 1986).

Phosphorus promotes the formation of lateral and fibrous roots which increases the absorbing surface for nutrients as phosphorus-starved plants have a stunted and poorly developed root system which decreases their feeding zone. Phosphorus increases the number of tillers in cereals. Phosphorus fertilisation hastens the ripening of plants. It also increases disease resistance in plants, presumably through normal cell development resulting in vigorous growth (Tamhane et al., 1970).

Phosphorus deficiency causes premature leaf fall and purple or red anthocyanin pigmentation. The growth of both shoot and root is restricted. Lateral shoots are fewer in number. Lateral buds may die or remain dormant and consequently blossoming is greatly reduced. The leaves become dark blue geen in colour and brown necrotic areas are developed on leaves and petioles. Phosphorus deficiency causes decrease in the rate of protein synthesis. It also results in the accumulation of carbohydrates and soluble nitrogenous compounds (Hewitt, 1963).

2.1.1.3 Potassium

Potassium is required in large amounts by plants. Unlike nitrogen and phosphorus, potassium does not form a stable structural part of any molecule inside the plant cell. Potassium activates the enzymes synthesising certain peptide bonds and enhances the incorporation of amino acids into protein (Webster, 1956). The enzymes that require potassium (K^+) as an activator include fructokinase, pyruvic acid kinase and trans-acetylase (Nason and McElroy, 1963). Potassium is essential for most metabolic processes, including glycolysis, oxidative phosphorylation and adenine synthesis (Evans and Sorger, 1966). It is involved in the translocation of solutes moving actively across the sieve plate by electro-osmosis (Salsibury and Ross, 1986). It also helps in opening and closing of stomata (Fischer and Hsiao, 1968; Humble and Hsiao, 1969).

Potassium deficiency results in chlorosis of older leaves first. Its deficiency causes necrosis, rosette or bushy habit of growth and weakening of stems and decreases resistance to pathogens. It also causes reduction in protein synthesis.

Low molecular weight compounds, such as amino acids and sugars, accumulate to unusually high levels while proteins and polysaccharides are reduced (Hewitt, 1963).

2.1.2 NPK requirement of mustard

The importance of supplying adequate and balanced amounts of NPK to ensure high yield and good quality of a crop cannot be over-emphasised. In the following pages an attempt has been made to review the available literature regarding the effect of these nutrients on the performance of mustard crop with particular reference on Indian publications. For the sake of convenience all measurements are given in S.I.units.

Maini *et al*. (1959) studied the effect of increasing doses of nitrogen 0, 33.6, 67.2 and 100.8 kg N/ha, applied as ammonium sulphate, on three varieties of mustard, viz., *Raya L-18* (*Brassica juncea*), *Brown Sarson* 'A' (*B. compestris*) and *Toria* '*A*' (*B. campestris*) grown in the erstwhile state of Punjab. They observed increase in yield of these varieties with increasing doses of nitrogen, 91.39, 66.53 and 26.88 kg N/ha proving optimum for *Raya*, *Sarson* and *Toria* respectively. It was found that *Raya* and *Brown Sarson* gave significantly higher yield in comparison with Toria.

Singh and Singh (1959) reported the results of the experiments conducted from 1954 to 1958 at Kanpur (U.P.). The experiments were carried out on two rai varieties, viz., RT-11 (early) and Laha-101 (late) and two yellow sarson varieties, viz., T-30 (early) and T-151 (late). The data revealed that manuring (and irrigation) gave significant increase in yield of both varieties. The varieties showed differential response. 33.6 kg N/ha was found to be the economic dose although the response was given upto 100.8 kg N/ha. With regard to the effect of phosphorus alone or in combination, it was observed that its application was ineffective on all varieties.

Sandhu and Singh (1960) reported that nitrogenous manuring of raya (*B. juncea*) at the rate of 33.6 kg N/ha and 67.2 kg N/ha gave a highly significant increase of 58% in seed yield over control.

Dalal *et al*. (1961) conducted experiment at Gurgaon (erstewhile Punjab) from 1953 to 1958 on Brown *sarson* (*B. juncea*), Brown *sarson* (*B. campestris*) and *Toria* (*B. campestris*). They studied the effect of varying levels of nitrogen, viz., 0, 33.6, 67.2 and 100.8 kg N/ha. Nitrogen was applied in the form of ammonium sulphate. They found that brown *sarson* and *Raya* crops gave highest yield with the use of 100.8 kg N/ha, whereas, 67.2 kg N/ha proved to be best for *Toria*. Further, they noted that application of 12.24 kg and 29.37 kg P/ha as superphosphate alone or in combination with varying nitrogen doses did not have marked effect on the performance of any of the *Brassica* crops.

Pathak *et al*. (1961) applied nitrogen (0, 28 and 56 kg N/ha) and phosphorus (0, 12.24 and 24.47 kg P/ha) alone and in different combinations in a field experiment conducted at Kanpur (U.P.) during 1958-1960 on *B. campestris* var. Yellow-*Sarson* and *B. juncea* (Rai). Among different combinations, 56 kg N + 24.47 kg P/ha gave maximum yield of 1,024.8 kg/ha over no (N+P) control giving 730.24 kg/ha yield. However, the combination 28 kg N + 12.24 kg P/ha proved most economical for Yellow-*Sarson*. This crop showed no response to phosphorus when applied alone. On the other hand, when phosphorus was applied in combination with nitrogen, 12.24 kg P/ha proved better than 24.47 kg P/ha. The application of the highest dose of nitrogen to Rai, either alone or in combination with 12.24 kg P/ha gave maximum yield and was found most economical.

Maini *et al*. (1963) studied the effect of three doses of nitrogen, i.e., 0, 33.6 and 67.2 kg N/ha on Toria (*B. campestris* var. *Toria Abohar*), in an experiment conducted at Patiala (Punjab) for three years from 1959-60 to 1961-62. A gradual increase in dry matter production, height, primary branches, and secondary branches/plant and seed yield was noted with increasing levels of nitrogen. However, plant height and primary branches/plant given by 33.6 kg N/ha and 67.2 kg N/ha were at par.

Majumdar and Sandhu (1963) applied nitrogen and phosphorus at the rate of 0, 28 and 56 kg N and 0, 12.24 and 24.47 kg P/ha respectively in field trials at I.A.R.I. (New Delhi) on *B. campestris* var. Brown *Sarson*. The data revealed that nitrogen application increased height/plant, number of primary branches, dry matter, number of pods, length/pod, total number of seeds and protein content but decreased the test weight and oil content of seeds significantly. However, its application increased total oil yield and seed yield. The doses 28 kg N/ha and 56 kg N/ha proved at par for most of the characters, including test weight, protein content, seed yield and oil yield. In the case of phosphorus application, only the number of total branches was increased significantly from 0 to 24.47 kg P/ha. The per cent nitrogen content in the seed and plant increased with increasing doses of nitrogen. However, the effect of 28 and 56 kg N/ha on seed nitrogen content was non-significant. Phosphate content of plant significantly increased with 28 kg N/ha. Application of phosphorus decreased the nitrogen content in seed and plant, and increased the phosphate content in plants.

Sharma (1968) reported from Meerut (U.P.) the results of trials conducted for three years on Laha-101 (*B. juncea*). Nitrogen at 0, 22.5 and 45 kg N/ha and phosphorus and potassium at 0, 5.03 and 9.83 kg P and 0, 9.54 and 18.65 kg K/ha were applied alone in the form of ammonium sulphate, single superphosphate and muriate of potash respectively. He noted that nitrogen at 22.5 and 45 kg N/ha increased the average yield to 658 and 811 kg/ha respectively compared to 540 kg/ha in the unfertilised control. Average yield was increased from 630 kg (given by unfertilised plots) to 714 kg/ha in plots receiving

9.83 kg P/ha. He further noted that application of 18.65 kg K/ha gave an average yield of 539 kg/ha compared to 483 kg/ha recorded in the unfertilised control.

Wankhede et al. (1970) conducted a field experiment at Sirsa (Haryana) on the 'Abohar' variety of Indian rape (B. campestris). The fertilisers were applied at the rate of 40 kg N + 8.74 kg P and 80 kg N + 17.48 kg P/ha. Half of the nitrogen was applied at sowing and half as top dressing at the time of thinning, whereas the total amount of phosphorus was applied at sowing. A no fertiliser control was maintained simultaneously. They reported that application of 40 kg N + 8.74 kg P/ha increased the number of branches/plant, capsules/plant, seed yield and oil yield/ha compared to the unfertilised control. Oil content decreased with fertiliser application. It was also noted that the higher fertiliser level had adverse effect on most of the parameters, including oil yield and oil content of the seed in comparison with control. However, the seed yield was higher than that of the control but was still lower than the lower dose of the nutrient.

Singh et al. (1971) conducted field trials at Hissar (Haryana) with brown sarson (B. campestris var. Dichotoma). They reported that application of 50 kg N with 10.93 kg P or 100 kg N with 10.93 kg P/ha gave yields of 1, 250 and 1,220 kg/ha respectively compared with 890 kg/ha in unfertilised plots. However, oil content was decreased by the application of fertilisers.

Singh and Tomar (1971) reported the result of field trial conducted at Kota (Rajasthan) during 1967-68 to 1969-70. They applied three levels of nitrogen, viz., 0, 70 and 140 kg N/ha with and without three combinations of phosphate and potassium (0:0, 0:41.45 and 21.85:41.45 kg P:K/ha). Nitrogen was applied in two splits, i.e, half at sowing and the rest at 40 days of crop growth. They noted that application of 70 and 140 kg N/ha, in addition to the basal application of phosphorus and potassium (21.85:41.45), gave average yields of 845 and 963 kg/ha respectively. Significant increase in average yield was also noted due to the individual application of 70 and 140 kg N/ha in comparison with the control, with the latter dose (140 kg N/ha) proving supersior to 70 kg N/ha.

Gupta _et al_. (1972) conducted a field trial with _B_. _campestris_ var. _Toria_ type-9at Kanpur (U.P.) consisting of ten combinations of nitrogen (0, 40 and 80 kg N/ha) and phosphorus (0, 13.11 and 26.22 kg P/ha). In addition a combination of 80 kg N + 26.22 kg P + 33.16 kg K/ha was applied. The data revealed that 80 kg N/ha gave higher yield (111% over control and 50% over 40 kg N/ha). Phosphorus alone or in combination increased the yield and the combination 80 kg N + 26.22 kg P was found the best. They added that phosphorus alone at both the levels showed slight increase in oil content, whereas, 80 kg N/ha with or without phosphorus decreased it. The dose 80 kg N + 26.22 kg P showed an increase in oil yield and protein content. Inclusion of K did not seem advantageous. However, oil percentage was higher in the NPK treatment in comparison with all combinations of N and P only. None of the treatments affected nitrogen and phosphorus content in the plant at various sampling stages.

Kinra _et al_. (1972), in a field experiment at Kanpur (U.P.), applied four levels of nitrogen (0, 50, 100 and 150 kg N/ha) to Indian mustard (_B. juncea_ var. _Appressed Mutant_). The nutrient was applied in two phases, half as basal dose and half at 40 days after sowing as top-dressing. They observed that application of 50, 100 and 150 kg N/ha increased by yield by 56, 83 and 71% respectively over the control.

Mehrotra _et al_. (1972), working with Indian mustard (_B. juncea_) var. RT-11) at Rampur (U.P.), applied four levels of nitrogen (0, 22, 44 and 66 kg N/ha) and two levels of phosphorus (0 and 9.61 kg P/ha) in various combinations. They found that the nitrogen and phosphorus content in the plants increased upto the branching stage and decreased thereafter. Highest concentration and uptake of nitrogen and phosphorus, seed yield, and oil and protein content were obtained with combined dose of 66 kg N + 9.61 kg P. They further noted an inverse relationship between oil and protein content of _Rai_ seeds.

Shekhawat _et al_. (1972) working at Jodhpur (Rajasthan) studied the effect of nitrogen (0, 30 and 60 kg N/ha), phosphorus (0, 13.11 and 26.22 kg P/ha) and potassium (0, 24.87 and 49.74 kg K/ha) supplied in all possible combinations on yield of mustard

(*B. campestris* L. var. *Sarson* Prain). Full dose of phosphorus and potassium was applied as basal dressing, whereas, half nitrogen was given as basal dressing and the remaining half as top-dressing at flowering. They reported that application of nitrogen at both the levels increased seed yield significantly over control. However, no significant difference was noted between 30 kg and 60 kg N/ha. Neither the doses of phosphorus nor of potassium had any significant effect on seed yield.

Singh *et al.* (1972) carried out field experiments at Hissar (Haryana) for two successive years from 1964-65 to 1965-66. They studied the effect of various levels of nitrogen (0, 74, 101 kg N/ha) on the performance of four varieties of Indian mustard (*B. juncea*), namely, RG-1, RG-3, RL-9 and RL-18. There was significant increase in average seed yield with increasing nitrogen levels. The dose 101 kg N/ha gave 51.3 and 10.5% more yield over the control and 74 kg N/ha respectively. In 1964-65, the response of these varieties to applied nitrogen did not differ from each other, However, in 1965-66, variety RG-3 significantly yielded more than the others. On an average, RG-3 gave 11.2, 9.2 and 8.8% more seed yield over RG-1, RL-9 and RL-18 respectively.

Singh and Yadava (1972) conducted experiments at Hissar (Haryana) on Indian rape (*B. campestris* L. var. *Toria*) for three successive years from 1968-69 to 1970-71. Nitrogen and phosphorus were applied in the form of calcium ammonium nitrate and single superphosphate respectively. They applied different fertiliser N + P levels (0 + 0, 40 kg + 8.74 kg/ha and 80 kg + 8.74 kg/ha). The data revealed that increasing the fertility level resulted in enhanced primary branches, pods/main shoot, pod length and grains/pod but decreased 1,000 seed weight. Seed yield was increased significantly with increasing fertility levels in 1968-69 but in the other two years, the effect of 80 kg N + 8.74 kg P/ha was not significant. Oil percentage of seeds increased upto 40 kg N + 8.74 kg P in the first year, whereas increasing fertility levels had depressing effect on this parameter during the other two years. However, oil yield followed the trend of seed yield during all the three years.

Dasgupta and Das (1973) conducted a field trial at Varanasi (U.P.) on *B. campestris* var. Yellow *Sarson* T-42 for two years. They applied three levels each of nitrogen phosphorus and potassium at the rate of 0, 50 and 100 kg N/ha, 0, 16.39 and 32.78 kg P/ha and 0, 31.09 and 62.18 kg K/ha respectively, separately and in all possible combinations. The fertilisers were applied as single dose at sowing, 1/2 at sowing and 1/2 after one month; and 1/3 at sowing, 1/3 after one month and 1/3 after two months. The data on averages of two years revealed a gradual increase in number of pods, length of pods, test weight of seeds and seed yield with increasing levels of nitrogen. Application of phosphorus also enhanced yield and its attributes. However, the response was not linear. There was no response to the levels of potassium. Oil content of seeds was found to decrease with increasing levels of nitrogen and it increasedslightly on application of the maximum dose of potassium; but there was no effect of phosphorus on oil yield.

In a field experiment conducted at I.A.R.I. (New Delhi) on raya (B. juncea var. Appressed Mutant), Dayanand and Mahpatra (1974) applied three levels of nitrogen, viz., 30, 60 and 90 kg N/ha to the soil at the time of sowing. Both 60 kg N/ha and 90 kg N/ha gave higher yield in comparison with 30 kg N/ha. However, the increase was significant only at the 60 kg N/ha level.

Singh et al. (1974) conducted an experiment on mustard (as well as linseed and sunflower) at Kota (Rajasthan) for three years (1966-67 to 1968-69). They applied nitrogen (0, 30 and 60 kg N/ha), phosphorus (0, 13.11 and 26.22 kg P/ha) and potassium (0, 24.87 and 49.74 kg K/ha) in nine different combinations. Phosphorus and potassium were applied as full dose at the time of sowing, whereas nitrogen application was split up in two, viz., half at sowing and half at first irrigation. A combined dose of 60 kg N + 26.22 kg P + 49.74 kg K/ha proved optimum for yield of mustard.

Bhan et al. (1975), working at Kanpur (U.P.) observed the effect of increasing levels of nitrogen, phosphorus and potassium on seed yield and its attributes in three varieties of mustard (B. juncea), namely, Appressed Mutant, APP-3 and T-16.

The fertilisers were given at three levels, viz., $N_0P_0K_0$, $N_{60}P_{13.11}K_{24.87}$ and $N_{120}P_{26.22}K_{49.74}$ kg/ha. They found that highest fertility level (120 kg N + 26.22 kg P + 49.74 kg K/ha) resulted in maximum yield (2,350 kg/ha) of mustard, giving differences of 318 and 526 kg/ha with the medium fertility level, viz., 60 kg N + 13.11 kg P + 24.87 kg K/ha and unfertilised control respectively. Fertiliser application increased the number of branches, siliqua/plant, seeds/siliqua, siliqua length. It also hastened the maturity of the crop. T-16 yielded significantly higher than Appressed Mutant and APP-3. Explaining their data, they further reported that T-16 out yielded other varieties due to its larger seed size and higher number of seeds/siliqua.

Chundawat et al. (1975) carried out experiments at Jaipur (Rajasthan) for two years (1969-70/1970-71) on *B. juncea* var. RL-18. They applied three levels each of nitrogen (0, 30 and 60 kg N/ha), phosphorus (0, 13.11 and 26.22 kg P/ha) and potassium (0, 24.87 and 49.74 kg K/ha) separately and in combination. Half of nitrogen was given at sowing as basal dressing and half at first irrigation as top-dressing. The data revealed a linear trend of increase in average yield with increasing nitrogen, phosphorus and potassium. However, the increase in yield with increasing dose of potassium was not significant. Highest yield of mustard was obtained when a combined dose of 60 kg N and 13.11 kg P/ha was applied.

Sahu and Behura (1975) performed field experiments at Bhubaneswar (Orissa) for two consecutive years (1971-72 and 1972-73) on *B. juncea* var. *Appressed Mutant*. They applied nitrogen as calcium ammonium nitrate, phosphorus as superphosphate and potassium as muriate of potash at the rate 0, 50 and 75 kg N/ha; 0, 10.93 and 21.85 kg P/ha and 0, 20.73 and 41.45 kg K/ha respectively. Nitrogen was applied in two equal splits, i.e., half at sowing and half at flowering. They reported that number of branches, number of pods and number of seeds were maximum with individual application of 75 kg N/ha. Combined dose of 50 kg N + 10.93 kg P + 20.72 kg K/ha gave the highest seed yield of 1,957 kg/ha over the control ($N_0P_0K_0$) which was 825 kg/ha. Maximum oil content of 34.95% was obtained with individual application of 21.85 kg P/ha.

Bhan and Singh (1976) reported the result of an experiment conducted at Kanpur (U.P.) on *B. juncea* var. T-16 during 1970-71. The treatments comprised five levels of nitrogen (0, 40, 80, 120 and 160 kg N/ha), three levels of phosphorus (0, 10.93 and 21.85 kg P/ha) and two levels of potassium (0 and 20.73 kg K/ha) applied alone and in all possible combinations. Nitrogen levels gradually increased the seed yield upto 120 kg N/ha. However, 160 kg N/ha caused a depression in seed yield. The values given by 40 kg and 80 kg N/ha differed significantly; but the effect of 80 and 120 kg N/ha was at par. Application of 21.85 kg P/ha increased the yield significantly over control.

The effect of potassium was beneficial at 20.73 kg K/ha over the control. The ancillary characters like plant height and branches and pods/plant responded to nitrogen and phosphorus application in the same manner as the seed yield. However, potassium did not show any beneficial effect on these characters, except pod number/plant which was increased. The authors concluded that, for optimum yield and profits, mustard crop may be fertilised with a combined dose of 80 kg N + 21.85 kg P + 20.73 kg K/ha in Central Uttar Pradesh.

Agarwal and Gupta (1977), working at Hardoi (U.P.), undertook a comparative study of two varieties of toria (B. campestris), namely, Toria T_9 and Lahia T_{36} during 1974-75 and 1975-76. They applied four levels of nitrogen (0, 25, 50 and 75 kg N/ha). Phosphorus and potassium were given uniformly at the rate of 8.74 kg P and 16.58 kg K/ha respectively. Nitrogen was applied in two splits, half at the time of sowing and half at first irrigation. They reported that pods/plant and seeds/pod were higher in T_{36} than in T_9, whereas, 1,000 seed weight was higher in T_9 which resulted in higher yield/plant than Lahia T_{36}. On an average there was increase in seed yield with increasing doses of nitrogen. However, in 1974-75 a decline was noted with 75 kg N/ha, with 50 kg N/ha giving significantly higher seed yield than 25 kg N/ha and the control. In 1975-76, 25 kg N/ha gave significantly higher yield over control but its value did not differ significantly from that given by 50 kg N/ha. However, for toria 50 kg N/ha appeared optimum on economical considerations.

Naqvi et al. (1977) conducted a factorial randomised field trial at Aligarh (U.P.) on mustard (B. juncea) var. Laha-101. The effect of basal phosphorus given at the rate of 8.74 and 17.48 kg P/ha (and foliar spray of 0.87 kg P/ha as sodium dihydrogen orthophosphate and 1 kg S/ha as sodium sulphate alone or combined, at flowering and fruiting stages) was studied on shoot length, fresh weight and dry weight. In addition 60 kg N and 33.16 kg K/ha was applied uniformly at the time of sowing. The data revealed that at flowering stage the dose 8.74 kg P/ha gave maximum values for shoot length and fresh weight of the plant. There was increase of 7.5 and 13.5% in length and fresh weight of plant respectively over control. However, at later stage (fruiting stage) there was linear response of phosphorus on shoot length, the higher dose (17.48 kg P/ha) increasing shoot length by 2.4% over control. At this stage (fruiting stage), the effect of 8.74 and 17.48 kg P/ha was at par for fresh weight giving 24.0% increase over control. Dry weight increased linearly at both stages, 17.48 kg P/ha giving 29.4 and 31.9% higher values respectively than control.

Jain and Jain (1979), in a field experiment conducted at Udaipur (Rajasthan), studied the effect of nitrogen, phosphorus and potassium on B. juncea var. T-59. The treatments included control (no fertiliser), 30 kg N/ha, 30 kg N + 10 kg P + 20 kg K/ha, 60 kg N + 10 kg P + 20 kg K/ha. They reported that the increase due to 30 kg N/ha in average seed yield over the control was 240 kg/ha. A further increase of 180 kg/ha was noted when 60 kg N/ha was applied. The inclusion of phosphorus and potassium in both the nitrogen treatments, though, giving higher yields, did not prove economical.

Aulakh *et al.* (1980) conducted experiments at Ludhiana (Punjab) for three consecutive years from 1975-76 to 1977-78 on yellow mustard (*B. campestris* var. BSH-1) and mustard (*B. juncea* vars. RLM-198 and RL-514) to test the effect of nitrogen and sulphur. Three levels of sulphur (0, 30 and 60 kg S/ha), in combination with 0, 25, 50 and 75 kg N/ha for yellow mustard and 0, 60, 120 and 180 kg N/ha for mustard, were applied. During the third year, the levels of nitrogen were changed to 0, 30, 60 and 90 kg N/ha for yellow mustard and 0, 50, 100 kg N/ha for mustard. Sulphur (applied as gypsum) and a uniform dose of 8.74 kg P as triple superphosphate was drilled. Nitrogen (as urea) was broadcastedbefore sowing. Var. BSH-1 was included in the trials each year while var. RLM-198 was grown in the first two years and var. RL-514 in the last year. They reported that in all the three years, seed yield of both mustard crops increased significantly with increasing rates of nitrogen and sulphur applied separately. However, maximum yields were noted only when high rates of nitrogen and sulphur were applied together. The adequate N/S ratio appeared to be 7.5:1 or less for the seed of these two mustard crops. Oil content of seed improved markedly with sulphur (but not with nitrogen) application. With regard to oil yield, it was noted that the highest combined dose of nitrogen and sulphur gave maximum oil yield in both crops. The average increase in oil yield was 79% in yellow mustard and 27% in mustard.

Patel *et al*. (1980) conducted a split-plot field experiment at Junagadh (Gujarat) on mustard (*B. juncea* var. Varuna) to observe the effect of four levels each of nitrogen (0, 25, 50 and 75 kg N/ha) and phosphorus (0, 10.93, 21.85 and 32.78 kg P/ha) applied separately (with three spacings). Full dose of phosphorus was applied at the time of sowing, while half dose of nitrogen (as urea) was applied at sowing and the remaining half as top-dressing, one month afterwards. For fertiliser treatments, they reported that 50 kg N/ha resulted in higher number of secondary branches, number of pods/plant and 1,000 grain weight and gave significantly higher yield than the other doses. Among different levels of phosphorus, 21.85 kg P/ha produced significantly higher yield. This increase was due to increase in the number of pods/plant.

Vir and Verma (1981) reported the results of a field experiment conducted at Agra (U.P.) for two years (1974-75 and 1975-76) on mustard (*B. juncea* var. T-59). The treatments comprised four levels of nitrogen (0, 30, 60 and 90 kg N/ha) and three levels of phosphorus (0, 13.11 and 26.22 kg P/ha) (with three row spacings). It was noted that among nitrogen levels, 60 kg N/ha and, among phosphorus levels, 13.11 kg P/ha proved better for pod number and seed yield. Oil content in seeds remain unaffected by nitrogen and phosphorus application.

Parvaiz et al. (1982) conducted a field trial at Aligarh (U.P.) on yellow mustard (B. campestris) var. Peeli Sarson and mustard (B. juncea) var. Laha-101 to study the effect of five combinations of nitrogen (N) and phosphorus (P), i.e., N_0P_0, $N_{40}P_{8.74}$, $N_{40}P_{17.48}$, $N_{60}P_{8.74}$ and $N_{60}P_{17.48}$. Potassium was applied uniformly at the rate of 33.16 kg K/ha. The data revealed that the treatment $N_{40}P_{17.48}$ gave maximum seed yield, oil yield, oil percentage and hecto-litre weight and increased 42.52, 89.59, 33.09 and 9.18% over their control. However, pods/plant (107.99% more than control) and seeds/pod (30.13% more than control) were maximum in the treatments $N_{60}P_{17.48}$ and $N_{60}P_{8.74}$ respectively. Of the two varieties, Laha-101 outyielded Peeli Sarson. Only the number of seeds/pod was more in Peeli Sarson. The interaction $N_{60}P_{17.48}$ X Laha-101 gave highest values for seed and oil yield.

Singh et al. (1982) conducted a field trial at Rewa (M.P.) on B. campestris var. sarson during 1976-77. The treatments consisted of four levels of nitrgoen (0, 15, 30 and 45 kg N/ha) (and four dates of sowing). All doses of nitrogen were given at sowing with 17.48 kg P/ha and 16.58 kg K/ha. The data revealed that the increasing doses of nitrogen increased plant height, branches/plant, number of pods/plant, number of seeds/pod, 1,000 seed weight and seed yield significantly. Nitrogen at 45 kg N/ha proved optimum for all characters studied. Oil content followed the same trend as noted for other attributes.

Afridi et al. (1983) conducted a field trial at Aligarh (U.P.), according to split-plot design, to study the effect of two combinations of nitrogen and phosphorus, i.e., $N_{30}P_{4.37}$ and $N_{60}P_{8.74}$ applied at the time of sowing (and foliar spray of 20 kg N, 0.87 kg P and 2 kg S/ha) on pods/plant, seeds/pod, hecto-litre weight, oil percentage, seed yield and oil yield of mustard (B. juncea) var. Laha-101. They reported that higher dose ($N_{60}P_{8.74}$) gave significantly maximum value and increased pods/plant, seeds/pod, seed yield and oil yield by 67.14, 8.32, 43.76 and 32.55% over the lower dose ($N_{30}P_{4.37}$). However, hecto-litre weight and oil percentage were higher in lower dose ($N_{30}P_{4.37}$). They added that low hecto-litre weight and oil percentage in $N_{60}P_{8.74}$ indicate that the higher dose of nitrogen in the absence of high phosphorus level depressed oil formation.

Parvaiz et al. (1983) conducted a factorial field trial at Aligarh (U.P.) on B. juncea var. Laha-101 and B. campestris var. Peeli Sarson. They observed the effect of the application of two levels of phosphorus 4.37 and 8.74 kg P/ha in the presence of 60 kg N and 33.16 kg K/ha applied uniformly. They reported that compared with lower dose, higher dose of phosphorus proved superior for all the characters. The increase in shoot length, fresh weight, dry weight, pod number/plant, seed number/pod, hecto-litre weight, oil percentage, seed yield and oil yield was 102.33, 350.0, 319.49, 110.99, 46.43, 1.39, 10.0, 90.18 and 109.05% over the respective control. Regarding varieties, it was noted that Laha-101 performed better than Peeli Sarson.

Samiullah _et al_. (1983) conducted a split-plot field trial at Aligarh (U.P.) to study the effect of two basal doses of N and P, i.e., $N_{40}P_{8.74}$ and $N_{60}P_{17.48}$ (and spray of $N_{20}P_{3.49}$ S_2) on yield and quality of six mustard (_B. juncea_ L. Czern. & Coss.) varieties, namely Appressed Mutant, R.75-2, RL-18, T-11, T-16 and Varuna. A uniform basal dose of 33.16 kg K/ha was applied at the time of sowing. The yield parameters included pods/plant, seeds/pod, hecto-litre weight, oil percentage, seed yield and oil yield. The quality parameters were acid value, iodine value and saponification value. The basal dose $N_{60}P_{17.48}$ increased pods/plant by 50.4, seeds/pod by 5.2, seed yield by 32.8 and oil yield by 29.1% over the respective value for $N_{40}P_{8.74}$. This dose ($N_{60}P_{17.48}$) decreased oil content by 1.0%. Higher dose of N and P lowered the iodine and saponification value by 0.5 and 0.8% respectively over the lower dose ($N_{40}P_{8.74}$). Among varieties tested, Varuna proved best and Appressed Mutant poorest.

Mohammad _et al_. (1984) conducted a simple randomised field trial at Aligarh (U.P.) to study the comparative performance of ten varieties of mustard (_B. juncea_), namely, Appressed Mutant, Pusa Kisan, Pusa Kranti, R.75-2, RIK-3, RL-18, RS-3, T-11, T-16 and Varuna. A uniform basal dose of 60 kg N, 17.48 kg P and 33.16 kg K/ha was applied at the time of sowing. The parameters studied were pods/plant, seeds/pod, hecto-litre weight, oil percentage, seed yield,oil yield, acid value, iodine value and saponification value. Among the varieties tested, Varuna was significnatly better than all others. It produced 48.5% more pods/plant, 55.3% more seed yield 51.9% more oil yield than RIK-3 whose performance was the poorest. On the other hand, variety RL-18 surpassed even Varuna by 5.1% in oil percentage. However, Varuna out yielded RL-18 in seed production by 29.5% and oil production by 23.3%. Maximum value for acid, iodine and saponification value were noted in RL-18, Appressed Mutant and Pusa Kisan respectively. It was concluded that Varuna performed best.

Samiullah et al. (1984) conducted a field trial on mustard (B. juncea var. Varuna) at Aligarh (U.P.) to study the effect of different combinations of phosphorus and potassium, applied at the rate of 17.48, 26.22 and 34.96 kg P and 33.16, 49.74 and 66.32 kg K/ha on pods/plant, seeds/pod, hecto-litre weight, oil content, seed yield and oil yield. A uniform dose of urea nitrogen at the rate of 90 kg N/ha was also applied at the time of sowing. The effect of phosphorus alone and in combination with potassium was found significant for all parameters studied. Phosphorus applied at the rate of 26.22 kg P/ha gave significantly higher values for all parameters, except hecto-litre weight. However, the effect of 26.22 kg P/ha for oil content was at par with that of 34.96 kg P/ha. Application of 26.22 kg P/ha increased pods/plant by 18.2%, seeds/pod by 5.1%, hecto-litre weight by 0.8%, seed yield by 12.3%, oil percentage by 3.2% and oil yield by 22.9% as compared with 17.48 kg P/ha. The combination 26.22 kg P + 33.16 kg K/ha proved optimum, producing about 12 and 23 % more seed yield and oil yield respectively than the control.

Mohammad et al. (1985) conducted a field experiment at Aligarh (U.P.) to study the effect of four levels of nitrogen, viz., 30, 60, 90 and 120 kg N/ha, on yield and quality characteristics of mustard (*B. juncea* var. Varuna). A uniform dose of 17.5 kg P, as monocalcium superphosphate, and 33.2 kg K/ha, as muriate of potassium, was also given before sowing. It was observed that 90 kg N/ha proved optimum for most of the parameters, including pod number/plant, seed number/pod and seed and oil yield/ha. Seed yield was 58.8% higher in 90 kg N/ha compared with the lowest dose (30 kg N/ha), the major contributing parameters being pod number/plant and seed number/pod which were increased by 20.4% and 16.9% respectively compared to 30 kg N/ha. Oil yield/ha was 50.2% higher in this treatment. However, iodine value showed a decreasing trend with increasing doses of nitrogen, saponification value was maximum in 30 kg N/ha but acid value increased with increasing nitrogen levels.

Samiullah et al. (1985 b), in a split-plot field trial conducted at Aligarh (U.P.), studied effect of nitrogen and phosphorus each applied at the rate of 40 and 60 kg N and 8.74 and 17.48 kg P/ha respectively (and foliar spray of 0, 5, 10, 15 and 20 kg N with or without 0.87 kg P and 2 kg S/ha) on yield characteristics of mustard (*B. juncea*) var. Varuna. A uniform basal dose of 33.16 kg K/ha was applied at the time of sowing. The parameters studied were pods/plant, seeds/pod, oil percentage, seed yield and oil yield. The sources of nitrogen, phosphorus and potassium were urea, monocalcium superphosphate and muriate of potash respectively. It was noted that the basal dose $N_{60}P_{17.48}$ gave maximum value for all parameters studied. The increase in pods/plant, seeds/pod, oil percentage, seed yield, and oil yield were 11.7, 5.8, 4.7, 22.9 and 28.9% respectively over $N_{40}P_{8.74}$.

2.2 Vitamins

Vitamins are organic compounds which are required in small amounts to maintain normal growth and proper development of organisms. However, they do not furnish energy and are not utilised as structural building blocks. Being essential co-enzyme for a number of enzymes, they are required for the transformation of energy and for the regulation of the metabolism of structural units. Vitamins were recognised in animals earlier than in plants because the latter being autotrophs, are capable of synthesising all of them except vitamin D.

Generally speaking, three distinct periods in the history of vitamin research can be categorised. The first period was characterised by the recognition of their existence. The second period was devoted mainly to the isolation of a number of vitamins in pure form and to the elucidation of their chemical structure. The final period was characterised by the recognition that these compounds, which were known for a long time to exert beneficial effects on the growth of micro-organisms and animals, were also necessary for the growth of higher green plants.

Funk in 1912 was the first to isolate an amine from rice husk and polishing that alleviated the symptoms of the disease "beriberi". He also proposed the generic term "vitamine" for it (Lehninger, 1982). Drumond (1920) dropped the terminal "e" of "vitamine" because many of the compounds of this group were not amines. The term "vitamin",coined by him, was accepted by later workers. Wagner and Folkers in 1964 attempted to give a comprehensive definition of vitamin that categorised it as:

(a) An organic compound.
(b) A component of natural food but distinct from carbohydrate, fat and protein.
(c) Being present in normal food in extremely small concentrations.
(d) Essential for normal health and growth.
(e) Causing specific deficiency symptoms when absent or not properly absorbed from the diet.
(f) Molecules that cannot be synthesised by the host and must, therefore, be obtained exclusively from the diet (distinction between vitamins and hormones).

Later, Folkers in 1969 gave a modified definition of vitamins by taking into account the knowledge about the biosynthesis of nicotinic acid, vitamin C and co-enzyme Q. It read as a vitamin is "an organic substance of nutritional nature present in low concentration as a natural component of enzyme systems and catalyses required reactions and may be derived externally to the tissues or by intrinsic biosynthesis" (Morton, 1974).

The vitamins are generally classifed on the basis of their solubility in water or fat. Included in the water soluble category are vitamin C (ascorbic acid) and a group referred to as the B-vitamins. The fat-soluble vitamins include vitamin A (carotene), vitamin D, vitamin E, vitamin K, vitamin Q (ubiquinone) and vitamin F (Noggle and Fritz, 1986).

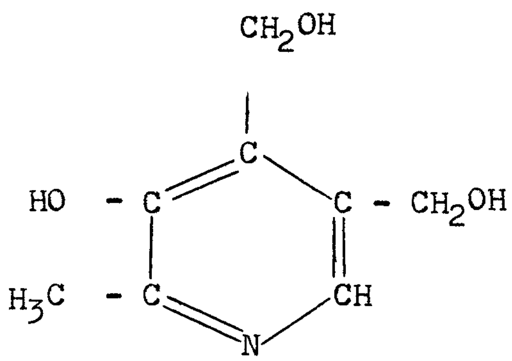
2.2.1 Vitamins of B-group

Keeping in view the specific nature of the problem reported in this thesis, which includes study of the effect of pyridoxine, a member of B-group of vitamins, it is necessary to discuss a little about B-vitamins in general and pyridoxine in particular. Investigations revealed that "B-vitamins" are a mixture of several compounds and have accordingly been renamed as "vitamin B complex". The vitamins isolated from this complex were numbered from B_1 to B_{12} and were named according to the class of chemical compounds to which they belonged. Thus, vitamin B complex includes vitamin B_1 (thiamine), vitamin B_2 (riboflavin), vitamin B_6 (pyridoxine), folic acid, nicotinamide, pantothenic acid, vitamin B_{12} (cyanocobalamine) and biotin.

2.2.1.1 Pyridoxine

György (1934) was the first to define and delineate vitamin B_6 as a distinct entity. It was isolated in crystalline form from yeast by Kuhn and Wendt, from rice polishing by

Keresztesy and Stevens and by Ichiba and Michi (Wiarde, 1938). The term pyridoxine was coined by György and Eckhardt in 1938 and was soon adopted by the American Institute of Nutrition (Schöpfer, 1949). Harris and Folkers (1939), Harris *et al.* (1939) and Stiller *et al.* (1939) established that vitamin B_6 was a pyridine derivative, being 2-methyl-3-hydroxyl - 4, 5-dihdroxymethyl pyridine. Stiller *et al.* (1939) and Kuhn and Wendt in 1939 proposed the following chemical structure of pyridoxine (empirical formula : $C_8H_{11}O_3N$):



Pyridoxine

Crystals of vitamin B_6, as a free base, are colourless rods of varying size with rounded ends and appear to have a tendency to coalesce in rosette or fan shaped formations (György, 1938). They melt at 160°C (Keresztesy and Stevens, 1938) and are readily soluble in water, alcohol and acetone. The vitamin is light sensitive and reacts easily with various acids to form salts. Vitamin B_6 is commercially available as heat stable, white hydrochloride salt empirical formula, $C_8H_{11}O_3N$-HCl). Its melting point is 204-206°C (Keresztesy and Stevens, 1938) and it is readily soluble in water (1 g in 4.5 ml) and alcohol (1 g in 90 ml).

Vitamin B_6 occurs in three active forms in living system, viz., pyridoxine, pyridoxal phosphate and pyridoxamine phosphate. Pyridoxal phosphate is the active group for the amino transferases, decarboxylases, various lyases and synthases. It has a role in the formation of lecithin, sphingosines and sphingomyelins (Karlson, 1975).

Several attempts have been made to investigate the role of vitamin B_6 in plants. It is suggested that the vitamin acts as a plant growth substance. Excised roots grow well in a sterile nutrient solution containing inorganic ions and sucrose, provided that they are supplied with vitamin B_6. However, little work has been done with entire plants. Also, the response of crops to the application of this vitamin has been observed only by very few workers who administered this (and other B-vitamins) either to seeds or to leaves. The researches regarding the effect of pyridoxine on the performance of plants do not, however, furnish complete information as is evident from the available literature reviewed below.

Bonner and Devirian (1939) reported that isolated pea roots can be cultivated indefinitely in the nutrient medium containing vitamin B_1 and nicotinic acid in addition to mineral salts and sucrose at the rate of 70-85 mm/week. However, addition of various chemical compounds, including vitamin B_6 (and adenine, ascorbic acid, theelin, β-alanine, pantothenic acid, vitamin E, K and B_2 and numerous amino acids) had no effect on the growth rate. The rate of growth of isolated radish roots was 15 mm/week when they were grown through 14 passages in the presence of vitamin B_1 and nicotinic acid. These vitamins were found indispensable to maintain normal growth of the roots of these plants. The addition of other chemical compounds listed above, was found ineffective. However, excised flax roots responded only to vitamin B_1 and grew at the rate of 150 mm/week. On the other hand, excised roots of tomato showed a growth rate of 40 mm/week in the presence of vitamin B_1 and B_6. This rate was further enhanced upto 60 mm/week on supplementing the nutrient medium with nicotinic acid.

Robbins and Schmidt (1939 a, b) found that addition of light brown sugar to the nutrient medium was more beneficial for the growth of excised tomato roots than pure cane sugar. Root growth decreased when light brown sugar was replaced by its ash (treated with hydrochloric acid) or pure cane sugar containing nicotinic acid, nicotinamide, thiamine and amino acids. However, addition of pyridoxine (vitamin B_6) to the pure cane sugar containing nutrient medium,promoted the growth of tomato roots. Addition of pyridoxine also induced the development of hooks and curls, indicating that it caused the elongation of cells. These observations implied that light brown sugar contained some "root growth factor".

Bonner (1940) investigated the requirement of the above "root growth factor" of several plants in vitro. Excised roots of alfalfa, clover and cotton needed vitamin B_1 and nicotinic acid for luxuriant growth, which did not improve further on the addition of vitamin B_6 in the nutrient medium. On the other hand, roots of Datura stramonium and sunflower showed profuse growth in the presence of vitamin B_1, B_6 and nicotinic acid. Similarly, isolated roots of carrot required vitamin B_1 and B_6 but the addition of nicotinic acid was of no use. In the case of five different strains of tomato, vitamins B_1 and B_6 proved beneficial for root growth which was further promoted by the inclusion of nicotinic acid into the medium. Lastly, excised roots of clover and flax were noted to synthesise vitamin B_1 in small amounts. Therefore, they maintained sub-optimal growth even in the absence of this vitamin.

White (1940) studied the effect of vitamin B_6, nicotinic acid and pyridine in the presence of sufficient thiamine in nutrient medium on growth of excised roots of two tomato strains. These strains of tomato did not significantly respond to vitamin B_6, nicotinic acid and pyridine. Therefore, he concluded that these strains of tomato contain adequate amount of these substances to support root growth under his experimental condition.

Day (1941) successfully cultivated excised tomato roots in agar-sucrose culture containing modified Pfeffers solution. To this, thiamine, pyridoxine, nicotinamide, neopeptone glutamic acid and glycine were added in different combinations. Development of hooks and curls was observed in excised tomato roots in all cultures containing pyridoxine (vitamin B_6). She also noted that neither of the two amino acids tested could replace vitamin B_6.

Minnum (1941 a,b) reported the results of two experiments one conducted in sand culture and another in field. In sand culture effect of crystalline vitamin B_1, B_2 and B_6 and "Vita Flor" was studied on growth of cauliflower and radish. "Vita Flor" contained 0.1% vitamin B_1, 0.5% nicotinic acid and traces of vitamin B_2, B_6 and pantothenic acid. These were given with Hoagland's nutrient solution and trace elements. In field trial crystalline B_1, B_2 and B_6 were replaced by brewer's yeast (containing B_1, B_2, B_6 etc.). The effect was studied on yield of beets, cauliflower, muskmelon, pepper, radish, rutabages, snap beans, summer squash, sweet corn and tomato. In both the experiments none of the treatments, including vitamin B_6, was found to have significant effect on the performance of these vegetables.

Robbins (1941) studied the effect of various vitamins on root growth of two inbred tomato lines, viz., Red currant and Johannesfeur, and their heterotic F_1 generation <u>in vitro</u>. Roots were supplied with thiamine, thiamine and pyridoxine, and thiamine, pyridoxine and nicotinamide in the culture medium.

The roots of F_1 produced more dry matter and showed better growth than either parent. However, the root growth of Red currant was luxuriant in the presence of thiazole which surpassed even the F_1 in one of the passages. Red currant also responded more to nicotinamide than Johannesfeur. The growth of Red currant became equal to that of hybrid F_1 if it was grown on a nutrient medium containing all the three vitamins. It seem that the three lines of tomato had got different ability for thiamine, pyridoxine or nicotinamide synthesis which was presumably responsible for the variable effect of the application of these vitamins on their root growth. On this basis, the maximum growth of hybrid F_1 roots was interpreted as if they had inherited the characteristics of synthesising adequate amount of these vitamins cumulatively. On the other hand, better root growth of the hybrid in the medium containing all three vitamins was explained by assuming higher synthesis of an unidentified growth factor in these roots.

Robbins (1942) also studied the effect of twelve analogues of pyridoxine on the growth of excised tomato roots in a medium supplemented with thiamine. Of these, three analogues hydrochloride of triacetate of vitamin B_6, hydrochloride of diacetate of vitamin B_6 and 2-ethyl 3-hydroxy-4, 5-bis-(hydroxymethyl)- pyridine hydrochloride were found as effective as pyridoxine itself. On the other hand, 2-methyl-3-amino-4-ethoxymethyl 5-amino methyl pyridine hydrochloride inhibited growth and 2-methyl-3-hydroxy-4-ethoxymethyl-5-hydroxy methyl pyridine hydrochloride had toxic effect. The rest of the compounds had neither beneficial nor detrimental effect. The author concluded that pyridoxine had a high degree of specificity and acetylation of pyridoxine did not reduce its activity for excised tomato roots. Methylation or ethylation of one of the hydroxymethyl groups, methylation of the phenolic hydroxy groups or replacement of one or more hydroxymethyl groups by methyl or amino groups reduced the vitamin activity or destroyed it entirely.

Noggle and Wynd (1943) germinated seeds of orchids *Cattleya trianae* var. *mooreana* and *C. schroederae* in an artificial nutrient medium in which maltose was applied as a source of carbohydrate. In this experiment, neither germination nor growth of seedling was obtained. It was also noted that the inability of seeds to germinate and to develop on the purified maltose medium was not overcome by the addition of vitamin B_1, ascorbic acid (vitamin C) or calcium pantothenate. However, a few seeds germinated and slow development of the seedlings occurred when riboflavin (vitamin B_2) was added in the medium. Moreover, presence of pyridoxine (vitamin B_6) and nicotinic acid showed good germination; but contrary to nicotinic acid, subsequent development with pyridoxine was poor.

Almestrand (1950) cultured excised roots of wheat in the presence of thiamine, pyridoxine and niacin. He found that pyridoxine alone had some effect on growth of wheat roots by increasing meristematic cell division. Optimum growth was obtained in pyridoxine concentrations ranging from 0.5 to 1.0 mg/l at 27-28°C.

Whaley et al. (1950) cultured excised tomato roots in White solution containing sucrose and glycine. This solution was supplemented with thiamine, niacin and pyridoxine. It was found that the roots required thiamine, niacin and pyridoxine for their optimal growth. Moreover, thiamine acted synergistically both with niacin and pyridoxine.

Almestrand (1951) also observed the effect of pyridoxine and two of its derivatives on the root growth of several strains of wheat, barley, oats and rye. In wheat strains, pyridoxine did not affect root growth of Ergo II, Virtus and Pondus markedly; but it enhanced the root growth of Eroica considerably. It was noted that no strain of barley, oats or rye responded to pyridoxine treatment. It was also observed that pyridoxine application enhanced the uptake of glucose, phosphate and nitrate in roots of the pyridoxine-sensitive variety Eroica. . Moreover, derivatives of pyridoxine, i.e.,pyridoxial phosphate and pyridoxamine, had similar beneficial effect to that of the mother compound.

Lee and Whaley (1953) studied the effect of thiamine, niacin and pyridoxine applied individually or in different combinations in culture media. In addition, there was a control containing no vitamin. The excised tomato roots were cultured for 4 weeks and the growth was determined at weekly intervals. They noted that there was no change in growth during the first week. Although the roots grown in media containing pyridoxine or niacin alone showed little increase in growth, compared with other media, it was significantly higher in those containing thiamine alone as well as in combinations of any two or three of the vitamins. Combination of all three vitamins showed highly significant effect. As the time of culture progressed, e.g., during third and fourth week, growth in all the media was markedly reduced. Lee and Whaley, therefore, concluded that the best period for investigation of the effect of growth substances under the experimental conditions was during the second and third weeks.

Boll (1954) cultured tomato roots to study the effect of thiamine, pyridoxine and niacin. He found that, for optimal growth of tomato roots, thiamine, pyridoxine and niacin are required. However, pyridoxine and niacin may be replaced by pyridoxal or pyridoxamine and niacinamide respectively. Moreover, the replacement of pyridoxine with glycine was greater in the presence of niacin. When the medium was supplemented with thiamine, pyridoxine and niacin, the addition of glycine at certain concentrations of pyridoxine increased the level of growth compared to the concentration of pyridoxine for optimum growth. Glycine exerted independent effect upon the initiation of laterals, whereas, the morphogenetic effects of glycine and pyridoxine were similar. The order of activity of pyridoxine and its replaceable form were pyridoxal > pyridoxine > pyridoxamine.

Fujiwara and Ojima (1954) studied the effect of thiamine, pyridoxine and nicotinic acid on the growth of excised root tips of rice and wheat in liquid medium. The addition of thiamine or pyridoxine accelerated the growth of rice roots, whereas, wheat roots showed marked response to pyridoxine.

Brusca and Haas (1957) studied the effect of several chemically pure salts of organic compounds on citrus in sand culture. Addition of vitamin B_6 (0.01 and 0.02 g/plant) and vitamin B_{12} (0.02 g/plant) to the nutrient solution was noted to stimulate the growth of citrus plants.

Barbieri (1959) observed the effect of vitamin B_1 and B_6 on pea, broad bean, beet and wheat plants in culture. It was found that vitamin B_1 and B_6 increased plant height, leaf number and fresh and dry weight. Moreover, the response was more pronounced with beat and less in pea and broad bean.

Vergnano (1959) studied the effect of vitamin B_1 and B_6 on rooting in cuttings of some plants in sand culture. Each vitamin was added to the nutrient solution at the rate of 0.01 mg/l. It was found that these treatments did not improve rooting in <u>Colutea arborescens</u> but <u>Herdera helix</u> and <u>Rosa</u> showed good response. Treated plants of <u>Rosa</u> showed greater number of buds and leaves and much larger leaf blades than the controls.

Skol'Nik and Davydova (1962) found that zinc deficiency symptoms produced in tomato plants were ameliorated by the application of vitamin B_1 and vitamin B_6 each applied at a concentration of 100 mg/l.

Kudrev and Pavlov (1965) flooded wheat variety Bulgaria No.301 at tillering, shooting and heading stage. They found that the treatment affected growth and development adversely and reduced yield by decrease in number and weight of grains. However, this ill effect was restored by spraying aqueous solutions of vitamin B_6. It was explained that the observed restoration of plant growth was due to normalisation of N-metabolism.

Das and Das (1966) studied the influence of thiamine and pyridoxine on the extension growth of isolated roots of pea. The two vitamins were applied at concentrations ranging from 0.01 ppm to 100 ppm. The control was grown with 0.5% sucrose only. It was found that optimum concentration of thiamine was 0.1 ppm and for pyridoxine it was 0.01 ppm. Otherwise, the broad spectrum of activity of the two compounds was similar.

Ovcharov and Kuleiva (1968) soaked cotton seeds for different periods in 0.01% solution of vitamin B_6, B_3 (PP) and nicotinic acid amide (aderivative of PP). Soaking of seeds for 1-3 h in PP and nicotinic acid amide increased water absorption by seeds after 3-6 h and dry weight of embryo after 12h. Seeds treated for 20h were sown in nutrient culture with different forms of N and P. In general, the vitamins increased germination and area of first leaf two to three fold. It was also observed that the effectiveness of vitamin B_6 depended upon the form of fertiliser applied. Root length of treated seedlings in the presence of ammonium sulphate was 49% more than in untreated seedlings. When calcium nitrate was used, root length decreased by 14%. Conversely, effectiveness of PP was not influenced by the form of fertiliser. It was observed that vitamin application increased N and P content in 2 d old seedlings. The increase in N and P content was more in the presence of KH_2PO_4 than in that of superphosphate.

Dimitrova-Russeva and Lilova (1969) studied the growth and essential oil synthesis of Mentha piperata as affected by vitamin B_1, B_6 and nicotinic acid in nutrient solution as well as in the soil. They observed that the effect of vitamins on growth was dependent on the environment. The uptake of nitrogen and phosphorus was increased by the application of vitamins, particularly that of phosphorus responded to a single application of nicotinic acid and double application of others. It was also noted that essential oil was increased by nicotinic acid and similar results were obtained with the double application of thiamine; but pyridoxine reduced it.

Popova et al. (1971) sprayed aqueous nicotinic acid amide (NAA), vitamin B_1, B_2, B_3 and B_6 in various combinations on the pistils of Capsicum soon after pollination. They observed that vitamins of B group increased fruit set and seed number/ fruit. The growing period was shortened and plant height was increased in F_1 generation. It was noted that all treatments (except vitamin B_2) improved earliness in F_1 generation.

Kozhin and Kravtsov (1973) studied the effect of pyridoxine, applied at concentrations of 0.001, 0.01, 0.1, 1.0 and 10.0 mg/l, on growth of isolated embryos of pear and apple at different stages of ripeness under sterile culture conditions. In the presence of pyridoxine, the embryo showed better germination and differentiation into seedlings. Accumulation of chlorophyll in seedlings was also enhanced. However, embryos from unripe seeds showed more pronounced response to the applied treatment than those of ripe seeds.

Gopala Rao _et al_. (1974) investigated the effect of biotin, pyridoxine, niacin and thiamine on succinic dehydrogenase, respiration and protein content of green gram (_Phaseolus radiatus_ L.) variety GG 525. The seeds were germinated in sterilised pitridishes. On the third day seedlings were transferred for 24h to fresh sterilised petridishes containing 10 ppm of the vitamins. The treatment enhanced enzyme activity in shoot as well as in root. In general, it was found to be less in the shoot than in the root. However, the enzyme activity in both root and shoot showed a reduction of the fourth day.

Pastena (1974) investigated the effect of vitamin A, B_1, B_2, B_6, B_{12} and C on cuttings of root stock of American vine. These cuttings were held for 24h in vitamin A, B_1, B_2 and B_6 at concentration of 125-250 ppm, B_{12} at 5-250 ppm and C at 150-25,000 ppm, and were then planted in nursery. It was noted that vitamin A, B_2, B_{12} and C had either no effect or inhibited root formation but growth was unaffected compared to control. On the other hand, although vitamin B_1 and B_6 also had an inhibiting effect on root formation, they enhanced cutting growth and average cutting weight.

Kulieva _et al_. (1976) carried out laboratory and field trials on melons and water melons to study the effect of vitamins on stem and root development at 45d and on the number and weight of fruits at 90d. Seeds and plants of these two crops were treated with thiamine, cyanocobalamine, nicotinic acid, pyridoxine and ascorbic acid at concentrations ranging from 0.01 to 0.0001%. The data revealed that maximum response with 0.001% thiamine, 0.0001% cyanocobalamine and 0.0001% nicotinic acid. Spraying was found effective in the case of 0.001% cyanocobalamine and 0.01% ascorbic acid only.

Afridi _et al_. (1979) studied the effect of soaking of seeds of barley variety K 572/28. The treatments comprised 0.0 (water-soaked), 0.1, 0.3 and 0.5% aqueous pyridoxine hydrochloride solution for 24h in petridishes. The soaked seeds were grown in sand to which Long Ashton nutrient solution was supplied. The data revealed that 0.3% solution was optimum for length, number and fresh weight of root/plant, giving 6.6, 19 and 27.7% increase respectively over the control. However, root dry weight was maximum with the application of 0.5% pyridoxine solution, being 24.2% higher than the control. Similarly, shoot characteristics were significantly optimum in 0.3% treatment. Number of tillers,leaf number, length and dry weight of shoot/plant were increased by 13.0, 13.5, 5.8, 15.0% in comparison to the control. Regarding chemical analysis, root carbohydrate and protein content were noted to be optimum in 0.5 and 0.1% treatment, being 4.9 and 10.9% higher respectively than in the control. This concentration of pyridoxine also gave 6.6 and 20.6% more shoot carbohydrate, and protein content respectively than the control. Further 0.3% soaking treatment enhanced ear weight by 2.8%, ear length by 8.2%, spikelet number by 10.8%, grain number by 12.9% and grain yield by 9.0%. However, straw yield was maximum (12.7% more than the control) in 0.5% soaking treatment. When the effect on grain quality was assessed, it was found that 0.3% gave maximum value for test weight and grain carbohydrate; whereas grain protein was maximum in 0.5% soaking treatment. They concluded that the effect was mainly due to enhanced root growth at the early stages. This was presumed to ensure better utilisation of soil moisture and nutrients which, in turn, increased the meristematic activity of the shoots, resulting in enhanced yield of grain.

Ahmad *et al.* (1981) studied the effect of vitamin B_6 on the growth of barley. They soaked the seeds of five varieties of barley, namely, NP13, NP21, K-572/10, K-572/28 and Clipper for 24h in aqueous pyridoxine hydrochloride solution of 0.0, 0.02, 0.1 and 0.5% concentrations and sowed them in 4.5 sq.m.miniplots. At the time of sowing, N, P and K were given at the rate of 80.0, 13.1 and 33.1 kg/ha in the form of urea, superphosphate and muriate of potash respectively. The growth characteristics observed were: tiller number, leaf number and length, fresh weight and dry weight of shoot. 0.1% pyridoxine treatment proved optimum for all characteristics studied at all growth stages except tiller number, leaf number and fresh weight at 70d where 0.5% pyridoxine treatment gave maximum value. The increase, in tiller number, leaf number and fresh weight and dry weight of shoot at 50, 70, 90d, due to the optimum treatment was 19.0, 19.7, 15.9 , 15.2, 18.8, 12.2, 21.7, 22.8, 23.1, 16.5, 24.3 and 20.5% over their respective control. Shoot length was significant only at 70 and 90d. The increase was 3.79 and 6.19% over the control. Among varieties, Clipper gave maximum response and lowest number of tillers were given by K 572/28; but the latter produced the tallest plants. NP21 had the maximum fresh and dry weights followed by K 572/28. The interaction effect of 0.02% pyridoxine X K 572/28 proved the best.

Ahmad *et al.* (1982) conducted a field experiment to study the effect of seed soaking of five barely varieties

NP13, NP21, K 572/10, K 572/28 and Clipper in 0.0, 0.02, 0.10 and 0.50% aqueous pyridoxine hydrochloride solution for 24h on their yield characteristics. These soaked seeds were sown according to factorial randomised block design. The mini-plots (4.55 sq.m.) received 80 kg N, 13.1 kg P and 33.1 kg K/ha applied in the form of urea, superphosphate and muriate of potash respectively at the time of sowing. Maximum grain yield was noted with 0.10% whereas straw yield was maximum with 0.02% pyridoxine, the two treatment giving 10.66% and 4.39% higher values compared with control. Variety K 572/28 outyielded the other varieties in grain yield, whereas NP21 produced maximum straw yield. Regarding interaction effect, 0.10 X K 572/10 and 0.02% pyridoxine X NP13 produced maximum grain and straw yield respectively.

Ashfaq et al. (1983) conducted a field trial to study the effect of soaking the grains for 12h in 0.0, 0.1, 0.2, 0.3 and 0.4% aqueous pyridoxine solution on seed germination and yield characteristics of triticale var. Bronco 90. Of the five treatments, 0.2% proved optimum for the characteristics studied, for example, this treatment enhanced grain yield by 37.7% over control.

Ansari and Samiullah (1984) conducted a simple randomised field experiment on lentil (Lens culinaris Medic. var. T-36) to study the soaking effect of pyridoxine on seeds. The seeds were soaked in 0.1, 0.2, 0.3, 0.4 and 0.5% aqueous pyridoxine solution for 12h. In addition to the treatment, water-soaked and unsoaked controls were taken for comparison. The effect was noted on pods/plant, pod length, seeds/pod, 1,000 seed weight and seed yield. Soaking in 0.3% solution proved optimum. It increased pod number, seed number and seed yield by 50.3, 14.5 and 17.7% but decreased 1,000 seed weight by 4.3% compared with the control.

Kodandaramaiah and Gopala Rao (1984) investigated the influence of B vitamins on photosynthesis in isolated chloroplats of Cyamopsis tetragonoloba. They found that several vitamins including pyridoxine, sprayed at concentrations ranging from 50 to 200 mg/l caused stimulation of photosynthetic carbon fixation in chloroplasts isolated from the leaves of treated plants. Thus, pyridoxine-sprayed plants provided chloroplasts that showed photosynthetic activity (upto 45% increase) next only to niacin (51% increase over the chloroplasts isolated from unsprayed controls). When chloroplasts, isolated from unsprayed plants were given 0.1 to 20 mg/l vitamins directly, pyridoxine at 5.0 g./l was found to be the optimum concentration for $^{14}CO_2$ fixation.

Raghava Reddy and Gopala Rao (1984) raised Brassica nigra Koch. in pots and sprayed 0, 100, 500 and 1,000 µM of citric acid and pyridoxine separately. It was noted that 100 µM pyridoxine solution induced early flowering, increased leaf area and enhanced plant height compared with the control. Similar response was noted with citric acid application. Moreover, its effect on leaf area was less pronounced than that of pyridoxine.

Gopala Rao and Raghava Reddy (1985) observed the effect of B-vitamins on the uptake of sodium, potassium, calcium and phosphorus in one week old Vigna radiata seedlings. Treatment with the vitamins promoted the uptake of these elements. Thiamine and biotin were found ineffective in the uptake of phosphorus; but riboflavin, pyridoxine and pantothenic acid increased the uptake of all four elements. Application of pyridoxine, pantothenic acid and nicotinic acid particularly showed more influence on potassium and phosphorus uptake than the other vitamins included in the study.

Samiullah et al. (1985 a) conducted two simple randomised field experiments at Aligarh (U.P.) to study the effect of pyridoxine treatment on root length, root nodule number, nitrate reductase activity (NRA) and yield of Vigna radiata var. K-851. In one experiment seeds of Vigna were soaked for 4h in 0.0 (control), 0.1, 0.2, 0.3, 0.4 and 0.5% aqueous pyridoxine solution. Root length, root nodule number and NRA were measured at 20, 30, 40 and 50d after sowing. It was noted that at 20 and 30d maximum root length was obtained in 0.2 and 0.3% soaking treatment, giving 12.9 and 36.7% more values than their respective control. At 40 and 50d maximum root length, was noted in 0.4% soaking treatment increasing values by 20.2 and 25.1% over their respective control. Moreover, root nodule number at 30, 40 and 50d was optimum in 0.3% soaking treatment which increased the number by 144.0, 25.1 and 25.3% over their respective control. Soaking in 0.3% pyridoxine solution increased NRA by 29.7, 7.1, 11.8 and 15.6% at 20, 30, 40 and 50d after sowing over their respective control. Seed yield was maximum in 0.3% soaking treatment (54.9% more than control).

In another experiment same concentrations of pyridoxine solution were applied to leaves either at pre-flowering (35d) or post-flowering (45d) stage. Root length, root nodule number and NRA were measured at 45 and 55d after sowing (10d after spray). For control plants were sprayed with water. It was noted that spray of 0.1% pyridoxine solution at pre-flowering proved optimum and enhanced root nodule number and NRA by 17.8 and 49.2% over their respective control. At post-flowering stage, 0.2% pyridoxine solution spray, gave optimum value for root length (45.4% more than control) and NRA (29.6% more than control). The increase in yield by 0.1 and 0.2% pyridoxine solution spray at pre-flowering and post-flowering stage was 33.7 and 26.4% respectively over the controls. On comparing the data of both experiments, it was concluded that soaking of seeds in pyridoxine solution was more effective than spraying. Moreover, seed treatment required smaller quantity of the vitamin than that of spraying for treating the same population of plants. It was suggested that seed treatment with dilute pyridoxine solutions may be exploited commercially as a simple, convenient and economical farm practice for ensuring high productivity.

Ahmad _et al_. (1986 a) carried out a factorial randomised field experiment to study the effect of pre-sowing soaking of seeds on yield attributes of five barley varieties, namely, NP13, NP21, K 572/10, K 572/28 and Clipper in 0.0, 0.02, 0.10 and 0.50% aqueous pyridoxine hydrochloride solution for 24h. The parameters included ear number/plant, ear weight/plant, ear length, spikelet/ear, grain number/ear, grain and straw yield/ha. It was noted that among the characteristics affected significantly by the treatment, ear weight/plant and grain yield/ha showed 10.4 and 10.6% increase over control in 0.1% pyridoxine solution, 4.8 and 5.3% increase over control in 0.02% pyridoxine treatment. However, ears/plant and straw yield/ha were maximum in 0.02% treatment (3.4 and 11.2% over control) but grain number/ear was affected aqually by all concentrations of pyridoxine. Varieties K 572/28 and NP21 showed maximum value for grain and straw yield respectively. The combination 0.02% X K 572/10 gave the best response for most attributes, including grain yield.

Ahmad _et al_. (1986 b) studied the effect of pre-sowing grain treatment of pyridoxine on test weight, carbohydrate content and protein content of five barley varieties, namely, NP13, NP28, K 572/10, K 572/28 and Clipper. Seeds were soaked for 24h in 0.0, 0.02, 0.10 and 0.50% aqueous pyridoxine solution.

Nitrogen (N), phosphorus (P) and potassium (K) was given uniformly at the rate of 80, 13.11 and 33.16 kg/ha respectively. They reported that soaking of barley grains in pyridoxine solution enhanced 1,000 grain weight, grain protein content. Grain carbohydrate and protein content/ha was maximum in 0.1% treatment. However, grain carbohydrate decreased with soaking. Among varieties K 572/28 surpassed all others in these characteristics. The combination 0.1 X K 572/28 gave maximum response.

Ansari and Khan (1986) carried out a simple randomised field experiment to study the effect of pyridoxine treatment on growth and yield performance of summer moong. Seeds of the short duration (60d) summer moong (*Vigna radiata* L. Wilczek cv. K-851) were soaked in 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5% aqueous pyridoxine hydrochloride solution for 4h before being sown in the field. Four growth characteristics (plant length, leaf number, fresh weight and dry weight) were noted at 20, 30, 40 and 50d after sowing. Net assimilation rate (NAR) was calculated for the periods 20-30, 30-40 and 40-50d. At harvest, yield characteristics, namely, pod number, pod length, seed number/pod and 1,000 seed weight were studied. The data revealed that soaking in 0.3% pyridoxine solution proved optimum for all growth characteristics, NAR and seed yield. However, plant length at 20d was maximum with 0.1% pyridoxine treatment. Plant length, leaf number, fresh weight and dry weight were enhanced by 20.2, 18.2, 27.8 and 23.6% at 30d, 7.7, 22.3, 66.7 and 50.0% at 40d and 9.6, 24.1, 18.4 and 50.0% at 50d grown in 0.3% treatment compared to control. NAR was enhanced by 19.3, 50.2 and 49.7% at 20-30, 30-40 and 40-50d interval respectively with 0.3% treatment. Regarding yield characteristics, 0.3% treatment proved optimum for all parameters, except 1,000 seed weight. Pod number, pod length and seed number/pod were enhanced by 45.0, 18.9 and 42.6% respectively over control. They concluded that soaking of seeds in aqueous pyridoxine solution may be utilised economically to enhance moong yield.

2.3 Concluding remarks

It is evident from the literature that aqueous solutions containing pyridoxine in small quantities increases the growth performance, productivity and quality of several agricultural and horticultural crops. However, such studies on oilseeds have not been conducted so far. Thus, it is considered highly desirable to study the effect of pre-sowing seed treatment with dilute pyridoxine solutions on the performance of mustard. It may be added that rapeseed-mustard is one of the major crops among the oilseeds cultivated in our country. It is no wonder that they occupy a high priority in the current Government strategy for improvement of agricultural production as edible oils have shown a persistent demand; production deficit during the last few decades and have been imported year after year in large quantities involving millions of dollars in foreign exchange.

CHAPTER - 3

MATERIAL AND METHODS

C O N T E N T S

MATERIAL AND METHODS

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MATERIAL AND METHODS

The field experiments on mustard (*Brassica juncea* L. Czern. & Coss.), reported and discussed in this thesis, were conducted in the 'rabi' (winter) season during 1983-86 at the Farm of the Aligarh Muslim University, Aligarh.

3.1 Agro-climatic conditions

Aligarh is one of the sixty districts of Uttar Pradesh (North India). It has an area of 5.024×10^9 sq.m. and is situated at 27°52' N latitude, 78°51'E longitude and 187.45 m altitude. Its climate is characteristic of western Uttar Pradesh, i.e., semi-arid and sub-tropical with hot dry summers and cold winters. The winter extends from the middle of October to the end of March. The mean temperature for December and January, the coldest months, is about 15°C and 14°C and the extreme minimum record for any single day is 2°C and 0.5°C respectively. The summer is hot, the average temperature for May is 34.5°C and for June 24°C whereas the extreme maximum record is 45°C and 45.5°C respectively. The average annual rainfall is 847.3 mm. More than 85% of the total rainfall occurs during June-September and some 10%, in the winter which benefits 'rabi' crops. These data were recorded at the

Meteorological Observatory, Department of Physics, Aligarh Muslim University, Aligarh.

Aligarh district possesses various types of soil, like sandy, loamy, sandy loam and clayey loam.

3.2 Soil characteristics

Before sowing, soil samples were collected from each plot upto a depth of about 10-15 cm. These were mixed thoroughly to get a composite sample. The composite sample was analysed in the Soil Chemistry Laboratory of the Indian Agricultural Research Institute (I.A.R.I.), New Delhi. The physico-chemical properties of the soil for each experiment are given in Table 1.

3.3 Field preparation

Before the rains set in, the field was thoroughly ploughed to ensure maximum soil aeration. It also helped in eliminating the weeds. After the rainy season, one ploughing was done again to eliminate the weeds. Standard agricultural practices required for mustard cultivation were employed. Finally, 10 sq.m. plots were prepared according to the design of each experiment and irrigated lightly before sowing to maintain proper moisture content in the sub-surface of the soil. The fertiliser was broadcast in each plot according to treatment just before sowing, that was done in furrows 13-15 cm deep, prepared by a small hand-drawn plough, at a seed rate given separately in each experiment.

Table 1: Physico-chemical characteristics of surface soil of the fields used for Experiments 1-4.

Characteristics	Year			
	1983-84	1984-85	1985-86	1985-86
	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH (1:2)	7.6	7.5	8.1	7.9
Conductivity E.C. (1:2) (m mhos/cm)	0.49	0.52	0.53	0.58
Available nitrogen (kg N/ha)	210.7	230.1	242.80	198.5
Available phosphorus (kg P/ha)	26.0	23.0	24.6	23.4
Available potassium (kg K/ha)	268.0	262.0	269.6	278.9

The four field experiments conducted in the three seasons (1983-86) are described separately below:

3.4 Experiment 1

The first experiment was conducted during 1983-84. The aim of the experiment was to study the comparative performance of nine newly evolved mustard varieties under four selected combinations of nitrogen and phosphorus. In addition to these varieties, Varuna an established variety, was included for comparison as it had been found in earlier studies to be best suited to this region (Mohammad, 1984). This trial was performed to select the varieties better adapted to local conditions with regard to their growth yield and quality characteristics. Authentic seeds of the ten varieties, namely, (1) KRV-47, (2) Pusa Bold, (3) PR-18, (4) RK-1467, (5) RK-8201, (6) RK-8202, (7) RK-8203, (8) RK-8301, (9) RK-8302 and (10) Varuna, were obtained from the I.A.R.I. Regional Research Station, Kanpur, Uttar Pradesh. The design of the field trial was factorial randomised block design and each treatment was replicated three times.

Two basal doses each of nitrogen and phosphorus at the rate of 60 or 90 kg N/ha and 20 or 30 kg P/ha in all possible combinations ($N_{60}P_{20}$, $N_{60}P_{30}$, $N_{90}P_{20}$, $N_{90}P_{30}$) were applied before sowing. A uniform basal dressing of 30 kg K/ha was also given with each of these combination (Table 2). The sources

Table 2: Summary of treatments for Experiment 1.

Varieties	Fertiliser treatments			
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$
KRV-47	+	+	+	+
Pusa Bold	+	+	+	+
PR-18	+	+	+	+
RK-1467	+	+	+	+
RK-8201	+	+	+	+
RK-8202	+	+	+	+
RK-8203	+	+	+	+
RK-8301	+	+	+	+
RK-8302	+	+	+	+
Varuna	+	+	+	+

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

Fertiliser treatments (F)	:	4
Varieties (V)	:	10
F x V	:	40
Replications	:	3
Design	:	Factorial randomised

of nitrogen, phosphorus and potassium were commercial grade urea, mono-calcium superphosphate and muriate of potash respectively. The size of each plot was 10 sq.m. (4 X 2.5 m). The seeds were tested before sowing for their viability. Healthy seeds of uniform size and weight were selected and treated with absolute alcohol for surface sterilisation. The seeds were sown by the usual "behind the plough" method at the rate of 10 kg/ha. The furrows were kept 22.5 cm apart and the number of seeds/furrow was maintained at 15. Sowing was done on 10 October, 1983. The field was irrigated thrice between sowing and harvesting. Weeding was done twice during the entire course of growth of plants. Two sprays of an insecticide (Dimecron 100) were applied at the time of aphid infestation, which coincided roughly with the flowering and fruiting stages. Sampling was done at 50, 70 and 90d after sowing to assess the growth pattern of crop. Net assimilation rate (NAR) was calculated for the periods 50 - 70d and 70 - 90d. Yield and quality charactteristics were studied at harvest.

3.5 Experiment 2

This field trial was conducted the next year, i.e., in the "rabi" season of 1984-85 in the same field that was used in the previous experiment. The aim of this trial was to investigate the effect of soaking the seeds of mustard in pyridoxine solution on growth, NAR, leaf NPK content, yield and quality characteristics of mustard. The optimum period for soaking was determined in the laboratory in petridishes in a preliminary investigation. Before soaking the seeds in pyridoxine hydrochloride solution, the native pyridoxine content of seeds was estimated (p. 67). Variety Varuna, on the basis of its superior performance in Experiment 1, was selected for the trial. Seeds of uniform size were surface-sterilised with absolute ethyl alcohol. Seeds were soaked for 4h in 0.0, 0.05, 0.10 and 0.20% aqueous pyridoxine hydrochloride solution (Table 3) and kept in separate conical flasks.

Soaked seeds were sown behind the plough in 10 sq.m. plots at the rate of 10 kg/ha on 12 October 1984. The rows were 22.5 cm apart and the number of seeds/row were kept uniform (15). Each treatment was replicated thrice. The experiment was laid out according to simple randomised block design. A uniform basal dose (60 kg N, 20 kg P and 30 kg K/ha), based on the findings of Experiment 1, was given to all plots before sowing. Nitrogen, phosphorus and potassium were given in the form of commercial grade urea, monocalcium superphosphate and muriate of potash respectively. The experimental field was irrigated thrice between sowing and harvesting. Weeding was done twice during the entire course of crop development.

Plants were sampled at 50, 70 and 90d after sowing for assessing the growth performance of the crop, including leaf NPK content. Net assimilation rate (NAR) was estimated for the

Table 3: Summary of treatments for Experiment 2.

Seed treatments
Soaked in water (control)
Soaked in 0.05% pyridoxine solution
Soaked in 0.10% pyridoxine solution
Soaked in 0.20% pyridoxine solution

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

Seed treatments	:	4
Variety	:	1 (Varuna)
Replications	:	3
Design	:	Simple randomised

periods 50-70d and 70-90d. At harvest, yield and quality parameters were studied.

3.6 Experiment 3

This field trial was conducted the next year, i.e., in the "rabi" season of 1985-86 in the same field that was used in the previous two experiments. The trial was based on the findings of Experiments 1 and 2. The object of the experiment was to observe the combined effect of selected combinations of nitrogen and phosphorus and soaking the seeds in pyridoxine hydrochloride solution and to determine their optimum combination for growth, yield and quality performance of mustard var. Varuna.

The experiment was conducted according to factorial randomised block design (Table 4). Each treatment was replicated thrice. The seeds were soaked for 4h in aqueous pyridoxine hydrochloride solution. The seed treatment comprised soaking in 0.0125, 0.025, 0.05 and 0.1% pyridoxine solution. In addition to these four seed treatments, two controls (unsoaked and water-soaked) were taken for comparison. In this experiment two concentrations of pyridoxine solution, 0.0125 and 0.025% were selected in addition to the pyridoxine concentrations taken in Experiment 2. In Experiment 2 soaking in 0.05% pyridoxine solution gave maximum values for most parameters and hence two lower concentrations were taken in the third field trial so as to determine the optimum concentration.

Table 4: Summary of treatments for Experiment 3.

Seed treatments	Fertiliser treatments		
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$
Unsoaked control	+	+	+
Water-soaked control	+	+	+
Soaked in 0.0125% pyridoxine solution	+	+	+
Soaked in 0.025% pyridoxine solution	+	+	+
Soaked in 0.05% pyridoxine solution	+	+	+
Soaked in 0.10% pyridoxine solution	+	+	+

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

Seed treatments (S) : 6

Fertiliser treatment (F) : 3

S x F : 18

Replications : 3

Design : Factorial randomised

Three combinations of nitrogen and phosphorus ($N_{60}P_{20}$, $N_{90}P_{30}$ and $N_{60+30}P_{30}$) were applied to the field. The first two combinations consisted of nitrogen at the rate of 60 and 90 kg N/ha and phosphorus at 20 and 30 kg P/ha respectively applied to the soil at the time of sowing. In the third combination, in addition to nitrogen and phosphorus added to the soil at the time of sowing at the rate of 60 kg N and 30 kg P/ha respectively, top-dressing of 30 kg N/ha was also done at 70d after sowing. Potassium was added uniformly to the soil at the rate of 30 kg K/ha at the time of sowing. Other agricultural practices, including irrigation, weeding and size of the plots were similar to the previous two experiments.

Plants from each plot were sampled at 50, 70 and 90d after sowing to assess the growth performance including leaf NPK content. Net assimilation rate (NAR) was calculated for the period 50-70d and 70-90d intervals. Yield and quality characteristics were studied at harvest.

3.7 Experiment 4

This experiment was conducted simultaneously with Experiment 3. The object of the trial was to study the effect of soaking of the seeds of three mustard varieties, namely RK-8203, PR-18 and Varuna. The varieties were selected on the basis of their performance in Experiment 1 and Varuna was included as check. The seeds of these varieties were soaked in 0.0125, 0.025, 0.05 and 0.10% pyridoxine solution. Two controls (unsoaked and water-soaked) were maintained for comparison. Each treatment was replicated thrice. The effect was assessed in terms of growth characteristics and NPK content of leaves at 50, 70 and 90d after sowing, net assimilation rate (NAR), calculated for the periods 50-70 and 70-90d of growth and yield and quality characteristics determined at harvest. The experiment was laid down according to factorial randomised block design and the scheme of the treatments is given in Table 5.

All the agricultural practices, including basal fertiliser dose, sources of fertilisers, irrigation, weeding and size of plots etc. were the same as in Experiment 2.

3.8. Sampling technique

Random samples of three plants were collected from each plot at the three growth stages, 50, 70 and 90d and at harvest for assessing growth performance, NAR and leaf NPK status, yield and quality of the crop. As the pods started maturing all the plants from each plot were harvested before pod shattering and thrashed to get seed yield.

3.9 Growth parameters

To assess growth, the following parameters were studied.

(a) Shoot length/plant

(b) Root length/plant

(c) Leaf number/plant

Table 5: Summary of treatments for Experiment 4.

Seed treatments	Varieties		
	RK-8203	PR-18	Varuna
Unsoaked control	+	+	+
Water-soaked control	+	+	+
Soaked in 0.0125% pyridoxine solution	+	+	+
Soaked in 0.025% pyridoxine solution	+	+	+
Soaked in 0.05% pyridoxine solution	+	+	+
Soaked in 0.10% pyridoxine solution	+	+	+

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

Seed treatments (S) : 6

Varieties (V) : 3

S x V : 18

Replications : 3

Design : Factorial randomised

(d) Fresh weight/plant

(e) Dry weight/plant.

3.10 Net assimilation rate (NAR)

NAR was calculated for the duration 50-70d and 70-90d of growth according to the following formula as described by Milthorpe and Moorby (1979):

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\ln L_2 - \ln L_1)}{(L_2 - L_1)}$$

$$\text{or;}\quad NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{2.303\,(\log_{10} L_2 - \log_{10} L_1)}{(L_2 - L_1)}$$

Here; W_1 = dry weight of whole plant at I growth stage

L_1 = leaf area of whole plant at I growth stage

t_1 = days of sampling at I growth stage

W_2 = dry weight of whole plant at II growth stage

L_2 = leaf area of whole plant at II growth stage

t_2 = days of sampling at II growth stage

ln = logarithm to base e

$\log_{10}$ = logarithm to base 10

3.11 Chemical analysis

(i) The pyridoxine content of seeds was estimated before sowing in the field.

(ii) Nitrogen, phosphorus and potassium contents of leaves were estimated at 50, 70 and 90d of growth on dry weight basis.

3.11.1 Estimation of pyridoxine

Seeds were dried and powdered. The powder was sieved and pyridoxine content was estimated colorimetrically according to the method of Hochberg *et al*. (1944a,b) which is described below:

3.11.1.1 Preparation of seed extract

1g seed powder was taken in a 20 ml calibrated test tube. 10ml of 4 N hydrochloric acid was added. The test tube was placed in a water bath and heated for 1h. The contents of the tube were stirred occasionally which helped in hydrolysing the bound pyridoxine as well as in extracting the vitamin. The solution was cooled and the pH was adjusted to 3 with 1N-sodium hydroxide and hydrochloric acid. At this pH, 3 ml of buffer (sodium citrate) was mixed followed by the addition of 2.5 g of Fuller's earth (formerly called Llyod's reagent). The tube was stoppered and shaken occassionally for 5 min. The suspension was centrifuged and the supernatant, discarded. The residue was washed with 15 ml of acidulated water. At this stage, 5 ml of 2 N-sodium hydroxide solution was added to the residue and the final volume was made upto 20 ml with distilled water. The suspension was dispersed for a period of

3 min by frequent inversions of the tube and centrifuged. A 10 ml aliquot of the eluate was taken and mixed with 50 ml of isopropanol and was again centrifuged. The clear supernatant was decanted and pH was adjusted to 5-7 by using a few drops of 12N-hydrochloric acid. This extract was used for pyridoxine estimation.

3.11.1.2 Colour development

The following tubes were setup in order to estimate the pyridoxine content in the seeds.

Test tube 1 : 6 ml test extract + 2 ml of ammonia - ammonium chloride solution + 1 ml of boric acid solution.

Test tube 2 : 6 ml of test extract + 2 ml of ammonia-ammonium chloride solution + 1 ml of distilled water.

Test tube 3 : 6 ml of test extract + 2 ml of ammonia-ammonium chloride solution + 1 ml of standard pyridoxine hydrochloride solution (10 μg).

In each test tube, 1 ml of 2,6 dichloroquinone chlorimide solution was added. Test tube 1 acted as the blank. The optical density was read at 660nm on "Spectronic 20" colorimeter exactly after 1 min of addition of 2, 6 dichloroquinone chloroimide reagent. The pyridoxine content in seeds was calculated by using the following formula:

$$\frac{L_2}{L_3 - L_2} \times \frac{10}{6} \times \frac{60}{10} \times \frac{18.5}{W} = \mu g \text{ pyridoxine/g seed powder}$$

In the above equation:

L_2= represents optical density of the solution present in Test tube 2.

L_3-L_2= represents increase in optical density due to the 10 μg pyridoxine added in test tube 3.

W = stand for weight of seed powder used,

$\frac{60 \times 18.5}{10}$ = is used for dilution factor.

3.11.2 Estimation of NPK

Three plants from each plot were randomly chosen and dried in an oven for 24h. Healthy leaves were plucked, powdered and passed through a 72 mesh screen. Nitrogen, phosphorus and potassium were estimated in the acid digested powder as described below:

3.11.2.1 Digestion of leaf powder

Leaf powder was digested for leaf nitrogen, phosphorus and potassium according to Lindner (1944). A 100 mg sample of dry leaf powder was taken in a 50 ml kjeldahl flask. To this was added 2 ml of chemically pure sulphuric acid followed by heating for 2h that turned the contents black. After cooling for 15 min, 0.5 ml of chemically pure 30% hydrogen peroxide was added drop by drop. The solution was again heated for about 30 min till the colour became light yellow. It was then cooled and 3-4 drops of hydrogen peroxide were again added. The contents were then heated for about 15 min to get a clear solution. Excess of hydrogen peroxide was avoided as it might oxidise ammonia in the absence of organic matter. The peroxide digested material was transferred to a 100 ml volumetric flask with three or four washings with distilled water and volume was made upto the mark.

3.11.2.1.1 Estimation of nitrogen

Lindner's method (1944) was adopted for the estimation of nitrogen in the samples.

A 10 ml aliquot of the peroxide-digested material was taken in a 50 ml volumetric flask. To this were added 2 ml of 2.5N sodium hydroxide and 1 ml of 10% sodium silicate solution to neutralise excess of acid to prevent turbidity respectively. The volume of the solution was made upto the mark with the help of distilled water. In a 10 ml graduated test tube, a 5 ml aliquot of this solution was taken and 0.5 ml of Nessler's reagent was added and mixed. The final volume was made up with distilled water. After waiting for 5 min to get optimum colour, optical density of the solution was determined at 525 nm of "Spectronic-20" colorimeter. A blank consisting of distilled water and Nessler's reagent was run simultaneously. A standard curve of known dilutions of ammonium sulphate solution was plotted. The reading of each sample was compared with this calibration curve and nitrogen in leaves was determined in terms of percentage on dry weight basis.

3.11.2.1.2 <u>Estimation of phosphorus</u>

Total phosphorus in the sulphuric acid-peroxide digest was estimated by the method of Fiske and Subba Row (1925). A 5 ml aliquot was taken in a 10 ml graduated test tube and 1 ml of molybdic acid (2.5% ammonium molybdate in 10 N-sulphuric acid) was added carefully, followed by the addition of 0.4 ml of 1-amino-2-nepthol-4 sulphonic acid. The colour turned blue. Distilled water was used to make up the volume to 10 ml. The solution was shaken, kept for 5 min and then transferred to a colorimetric tube. The optical density was read at 620 nm on a "Spectronic-20" colorimeter. A blank was used simultaneously with each determination. The standard curve was prepared by using known concentrations of monobasic potassium phosphate solution. The readings of samples were compared with this curve and phosphorus content in leaves was computed in terms of percentage on dry weight basis.

3.11.2.1.3 <u>Estimation of potassium</u>

Potassium content was estimated flame photometrically. A 10 ml aliquot was taken and it was read by using the filter for potassium. A blank was run side by side. The readings were compared with a calibration curve plotted from known dilutions of a standard potassium sulphate solution. The potassium in leaves was expressed as per cent on a dry weight basis.

3.12 Yield parameters

The following parameters were studied for yield assessment at the time of harvest.

(a) Pod number/plant
(b) Seed number/pod
(c) Hecto-litre weight of seeds
(d) Seed yield (kg/ha)
(e) Oil content (%)
(f) Oil yield (kg/ha).

3.12.1 Preparation of seed sample for oil analysis

The inclusion in the harvest that were larger than the seeds were separated by screening with the aid of a sieve which allowed only the seeds to pass through. The smaller dust particles were removed with the help of another appropriate sieve. Thereafter, seeds were crushed to get a fine meal for extracting the oil.

3.12.2 Determination of oil content

To assess the oil content, 25 g of seed meal was transferred to a soxhlet apparatus to which sufficient quantity of pure petroleum ether was added. The apparatus was kept in a hot water bath, running at 60°C for about 6h for complete extraction of the oil. The petroleum ether, containing the extracted oil, was evaporated. The extracted oil was expressed as a percentage by weight and was calculated by the following formula:

$$\frac{100 \times m}{m_o}$$

where m is the sum of the weight (g) of oil and m_o, the weight (g) of the seed sample.

3.13 Quality characteristics

The oil was analysed for the following quality characteristics:

(a) Acid value

(b) Iodine value

(c) Saponification value

3.13.1 Determination of acid value

The acid value is the number of mg of potassium hydroxide (KOH) required to neutralise free acid in 1g of substance. It was determined by the following method.

A small sample of 2g of the oil was taken in a 250 ml conical flask and 50 ml of solvent mixture (Appendix) added to dissolve the oil. Titration was carried out with 0.1 N potassium hydroxide solution (Appendix) using phenolphthalein

(Appendix) as an indicator. Number of ml 'X' of 0.1 N potassium hydroxide required was noted. The acid value was calculated by the following formula:

$$\text{Acid value} = \frac{'X' \times 0.00561 \times 1000}{W}$$

where 'W' is weight (g) of oil (Anonymous, 1970).

3.13.2 <u>Determination of iodine value</u>

The iodine value of oil is the number of the halogen absorbed by 100 g of oil and expressed as the weight of iodine. It was determined by iodine monochloride method given below.

A 2 g sample of accurately weighted oil was placed in a dry round bottom flask. To it, 10 ml of carbon tetrachloride and 20 ml of iodine monochloride solution (Appendix) were added. The flask was stoppered and allowed to stand in a dark place for about 30 min. Thereafter, 15 ml of potassium iodide solution (Appendix) and 100 ml of double distilled water were poured with gentle shaking. Titration was carried out with 0.1 N sodium thiosulphate solution (Appendix) using starch solution (Appendix) as an indicator. Number of ml, i.e., 'a' of sodium thiosulphate solution was noted. For blank, the same operation was carried out but without oil. The number of ml, i.e., 'b' of 0.1 N sodium thiosulphate required for the blank was also noted. Iodine value was calculated by the following formula:

$$\text{Iodine value} = \frac{(b-a) \times 0.01269 \times 100}{W}$$

where 'W' is the weight (g) of oil taken (Anonymous,1970).

3.13.3 Determination of saponification value

The saponification value is the number of mg of potassium hydroxide required to neutralise the fatty acids resulting from the complete hydrolysis of 1g of oil.

As for the other quality determinations, 2 g of the oil was weighed accurately in a 250 ml conical flask. To this, 25 ml of 0.5 N potassium hydroxide solution (Appendix) was added. The flask was attached to a reflux condenser and boiled on a water bath for about 1h with frequent rotation of the contents of the flask. After cooling, 1 ml phenolphthalein solution was added. The excess of alkali was titrated with 0.5 N hydrochloride solution (Appendix). The number of ml, i.e., 'X' was noted. For blank, the operation was repeated in the same manner omitting the oil, and the number of ml, i.e., 'Y' required was noted. Saponification value was calculated by the following formula:

$$\text{Saponification value} = \frac{(Y - X) \times 0.02805 \times 1000}{W}$$

where, 'W' is the weight (g) of oil (Anonymous, 1970).

3.14 Statistical analysis

All the data were analysed statistically according to the design of the experiment as per Panse and Sukhatme (1985).

The "F" test was applied to assess the significance of the data at 5% level of probability. The models of the analysis of variance (ANOVA) are given in Table 6 . Critical difference (C.D.) was calculated to compare the effect of various treatments.

Association of various growth parameters, NAR and NPK content in leaves with seed yield was determined by computing correlation coefficients (r). The significance of correlation coefficient values at 5% level of probability was determined. For these calculations, the following formula was used:

$$r = \frac{(X - \bar{X})\ (Y - \bar{Y})}{\sqrt{(X - \bar{X})^2 X\ (Y-\bar{Y})^2}}$$

X = independent character ($\bar{X}$ = mean)

Y = dependent character ($\bar{Y}$ = mean)

Table 6: Models of analysis of variance (ANOVA) of Experiments 1-4.

Experiment 1 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Fertiliser treatments (F)	3			
Varieties (V)	9			
F x V	27			
Error	78			
Total	119			

Experiment 2 (Simple randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Seed treatments	3			
Error	6			
Total	11			

Experiment 3 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Seed treatments (S)	5			
Fertiliser treatment (F)	2			
S x F	10			
Error	34			
Total	53			

Experiment 4 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Seed treatments (S)	5			
Varieties (V)	2			
S x V	10			
Error	34			
Total	53			

CHAPTER - 4

EXPERIMENTAL RESULTS

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CHAPTER 4

EXPERIMENTAL RESULTS

4.1 Experiment 1

In this factorial randomised field experiment, the effect of four combined doses of nitrogen and phosphorus was studied on growth, net assimilation rate, seed yield, oil content, oil yield and quality characteristics of KRV-47, Pusa Bold, PR-18, RK-1467, RK-8201, RK-8202, RK-8203, RK-8301, RK-8302 and Varuna varieties of mustard. The varietal differences and the interaction effect (FxV) were also observed on the above mentioned parameters (Table 7-14).

4.1.1 Growth characteristics

Growth characteristics, studied at three stages of growth (50, 70 and 90d after sowing), corresponding to vegetative, flowering and fruiting stages, included shoot length, leaf number, fresh weight and dry weight. The data are briefly described below and are summarised in Tables 7-10.

4.1.1.1 Shoot length/plant

The effect of basal fertiliser, varietal response and their interaction was found significant at 50 and 70d only (Table 7).

Table 7: Effect of selected combinations of nitrogen and phosphorus on shoot length/plant (cm) of ten varieties of mustard.

Varieties	Sampling days after sowing														
	50					70					90				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}N_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	**Mean**	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	55.30	61.65	66.08	69.62	63.16	117.49	110.56	125.39	116.11	117.39	124.98	133.36	139.12	148.31	136.44
Pusa Bold	63.57	70.26	53.33	65.46	63.16	93.89	112.61	95.42	116.99	104.73	129.74	126.16	133.94	131.25	130.27
PR-18	69.55	52.26	53.95	49.18	56.24	96.89	95.89	120.99	103.61	104.35	132.69	139.61	138.60	143.26	138.54
RK-1467	62.78	53.15	52.36	42.57	52.72	101.44	98.83	83.55	73.72	89.39	125.43	127.87	133.89	140.78	131.99
RK-8201	54.25	60.55	68.82	72.78	64.10	117.11	101.49	103.99	97.74	105.08	128.03	130.75	143.22	145.62	136.91
RK-8202	55.80	63.83	50.70	57.37	56.93	98.92	107.66	113.49	116.67	109.19	153.47	137.55	149.58	131.81	143.10
RK-8203	68.99	79.85	56.88	60.29	66.50	110.08	122.33	127.16	138.83	124.60	123.60	125.30	128.05	128.69	126.41
RK-8301	63.12	65.08	63.17	69.08	65.11	88.11	93.08	101.33	109.66	98.05	114.17	101.69	129.28	121.80	116.74
RK-8302	58.07	59.53	60.22	66.34	61.04	91.05	101.28	112.72	115.33	105.09	131.03	138.47	127.49	129.46	131.61
Varuna	56.24	48.49	60.82	58.00	55.89	101.22	91.00	109.66	103.67	101.39	134.22	135.80	123.35	125.08	129.61
Mean	60.77	61.46	58.63	61.07		101.62	103.47	109.37	109.23		129.74	129.66	134.65	134.61	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
Fertiliser treatment (F)	1.69	5.75	N.S.
Variety (V)	2.67	9.09	N.S.
F x V	5.34	18.17	N.S.

N.S. Non-significant

Among different fertiliser doses, at 50d, $N_{60}P_{30}$ gave maximum value. However, the value was at par with those for $N_{90}P_{30}$ and $N_{60}P_{20}$. The lowest value was obtained with the treatment $N_{90}P_{20}$, being at par with that for $N_{60}P_{20}$. At 70d, the maximum shoot length was noted with the treatment $N_{90}P_{20}$. The value given by this treatment was, however, at par with those for $N_{90}P_{30}$ and $N_{60}P_{30}$. The lowest vvalue for shoot length was recorded with $N_{60}P_{20}$ which was equal to $N_{60}P_{30}$.

Regarding varietal response, RK-8203 produced tallest plants at both (50 and 70d) stages of growth. However, at 50d the response was equal to those of RK-8301 and RK-8201 and, at 70d to that of KRV-47. Variety RK-1467 produced shortest plants at 50d and 70d. At both stages, the values differed critically from each other, except those given by RK-1467 and RK-8301 which were statistically equal at 70d stage.

Regarding interaction effects at 50d, the tallest plants were observed in $N_{60}P_{30}$ X RK-8203, the effect being significantly different from all other interactions. Significantly, shortest plants were produced by $N_{90}P_{30}$ X RK-1467. At 70d, the tallest plants were produced by $N_{90}P_{30}$ X RK-8203 which was at par with $N_{90}P_{20}$ X RK-8203, $N_{90}P_{20}$ X KRV-47, $N_{60}P_{30}$ X RK-8203 and $N_{90}P_{20}$ X PR-18. The minimum shoot length was recorded with $N_{90}P_{30}$ X RK-1467. The value differed critically from those for most of the other interactions.

4.1.1.2 Leaf number plant

The effect of various basal treatments as well as of the interaction on leaf number/plant was significant at all stages of growth. So were the varietal differences (Table 8).

At 50d, leaf production was significantly maximum in treatment $N_{60}P_{30}$. The minimum leaf production was noted with $N_{90}P_{20}$ and it was equal in its effect with the rest of the treatments. At 70 and 90d, treatments $N_{60}P_{20}$ and $N_{60}P_{30}$ (being equal in their effects) produced more leaves in comparison with other treatments. The lowest number of leaves was recorded in $N_{90}P_{30}$ at both the stages, However, it was at par with $N_{90}P_{20}$ at 70d and with $N_{90}P_{20}$ and $N_{60}P_{20}$ at 90d.

Varuna produced significantly maximum leaves at 50d and the value differed critically from the rest of the varieties, except RK-8301. Minimum leaf production was noted in RK-8201 but it was at par with RK-8202. At 70d, Pusa Bold significantly surpassed all varieties, except RK-8301, which equalled it. At this stage, the minimum number of leaves was noted in RK-1467, being at par with RK-8201, RK-8302, RK-8202 and KRV-47. At 90d, Varuna again performed best, giving significantly higher value in comparison with all other varieties, except PR-18. The minimum number of leaves was recorded in RK-1467 being at par with RK-8201 and KRV-47.

Regarding interactions at 50d, $N_{90}P_{30}$ X Varuna produced maximum leaves but was equalled by $N_{60}P_{30}$ X RK-1467, $N_{60}P_{30}$XVaruna,

Table 8: Effect of selected combinations of nitrogen and phosphorus on leaf number/plant of ten varieties of mustard.

Varieties	Sampling days after sowing														
	50					70					90				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	9.30	8.20	8.63	7.20	8.33	16.99	13.44	11.44	10.89	13.15	24.00	22.22	21.44	20.11	21.94
Pusa Bold	8.30	6.86	8.45	7.30	7.73	21.89	13.88	22.00	16.16	18.48	29.22	27.89	26.83	26.50	27.61
PR-18	7.20	9.30	6.95	7.96	7.85	14.66	18.33	11.49	15.11	14.89	34.22	36.11	30.34	29.70	32.59
RK-1467	8.53	10.96	7.43	6.53	8.36	12.78	15.33	10.11	9.33	11.89	19.56	26.60	18.00	16.99	20.29
RK-8201	7.26	6.45	6.43	5.30	6.36	15.67	12.33	11.55	10.83	12.59	25.00	21.84	20.00	17.90	21.19
RK-8202	6.45	8.60	5.80	7.73	7.15	14.49	15.00	10.33	11.67	12.87	26.00	27.83	21.67	22.00	24.38
RK-8203	7.60	8.50	8.06	8.86	8.26	14.49	16.58	15.83	16.99	15.97	21.89	26.34	29.33	30.33	26.97
RK-8301	9.30	8.95	10.40	9.30	9.49	17.78	16.13	19.78	17.89	17.39	28.67	26.34	31.67	30.00	29.17
RK-8302	7.96	8.83	7.50	8.90	8.29	11.99	13.88	11.77	13.21	12.71	25.00	27.55	24.89	26.00	25.86
Varuna	8.06	10.45	9.63	11.30	9.86	12.50	15.11	14.83	16.11	14.64	30.33	35.17	34.34	36.04	33.97
Mean	7.99	8.71	7.93	8.04		15.32	15.00	13.91	13.82		26.39	27.79	25.85	25.56	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Fertiliser treatment (F)	0.59	0.96	1.82
Variety (V)	0.93	1.52	2.88
F x V	1.86	3.03	5.75

$N_{90}P_{20}$ X RK-8301 and $N_{90}P_{20}$ X Varuna. At this stage, $N_{90}P_{30}$ X RK-8201 produced minimum number of leaves. However, its effect was statistically equal to those of $N_{90}P_{20}$ X RK-8202, $N_{90}P_{20}$ X RK-8201, $N_{60}P_{30}$ X RK-8201, $N_{60}P_{20}$ X RK-8202, $N_{60}P_{30}$ X Pusa Bold and $N_{90}P_{20}$ X PR-18. At 70d, $N_{90}P_{20}$ X Pusa Bold gave maximum number of leaves. The value given by this interaction was, however, equal to those of $N_{60}P_{20}$ X Pusa Bold and $N_{90}P_{20}$ X RK-8301. The minimum number of leaves was noted in $N_{90}P_{30}$ X RK-1467. The value was, however, at par with several other interactions, including $N_{90}P_{20}$ X RK-1467, $N_{90}P_{20}$ X RK-8202, $N_{90}P_{30}$ X RK-8201, $N_{90}P_{30}$ X KRV-47, $N_{90}P_{20}$ X KRV-47, $N_{90}P_{20}$ X PR-18, $N_{90}P_{20}$ X RK-8201, $N_{90}P_{30}$ X RK-8202, $N_{90}P_{20}$ X RK-8302, $N_{60}P_{20}$ X RK-8302 and $N_{60}P_{30}$ X RK-8201. At 90d, maximum number of leaves was produced by $N_{60}P_{30}$ X PR-18. The value given by this interaction was at par with those for $N_{90}P_{30}$ X Varuna, $N_{60}P_{30}$ X Varuna, $N_{90}P_{20}$ X Varuna, $N_{60}P_{20}$ X PR-18 and $N_{90}P_{20}$ X RK-8301. Minimum number of leaves was noted with $N_{90}P_{30}$ X RK-1467. The effect of this interaction was equal to those for $N_{90}P_{30}$ X RK-8201, $N_{90}P_{20}$ X RK-1467, $N_{60}P_{20}$ X RK-1467, $N_{90}P_{20}$ X RK-8201, $N_{90}P_{30}$ X KRV-47, $N_{90}P_{20}$ X KRV-47, $N_{90}P_{20}$ X RK-8202, $N_{90}P_{30}$ X RK-8201, $N_{60}P_{20}$ X RK-8203, $N_{90}P_{30}$ X RK-8202 and $N_{60}P_{30}$ X KRV-47.

4.1.1.3 Fresh weight/plant

The effect of basal fertiliser treatment,varietal response and their interaction regarding fresh weight was found significant at all the three stages of growth (Table 9).

Table 9: Effect of selected combinations of nitrogen and phosphorus on fresh weight/plant (g) of ten varieties of mustard.

Varieties	Sampling days after sowing														
	50					70					90				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
HRV-47	30.00	38.67	25.00	26.90	30.14	98.21	125.22	61.21	58.25	85.72	170.62	220.23	110.13	168.25	167.31
Pusa Bold	28.00	27.23	29.00	28.27	28.13	102.32	100.16	92.00	100.33	98.71	170.00	170.97	120.67	172.36	158.50
PR-18	22.00	45.11	27.33	29.14	30.89	72.41	150.44	57.13	98.67	94.66	110.68	260.12	125.25	175.81	167.97
RK-1467	25.40	51.38	29.11	26.53	33.11	76.72	170.13	66.25	70.42	95.88	120.25	270.16	121.11	110.65	155.54
RK-8201	28.80	42.00	25.22	21.78	29.45	78.67	100.24	64.11	78.14	80.29	135.11	230.32	120.01	112.37	149.45
RK-8202	18.70	24.21	15.67	31.25	22.46	62.38	67.11	52.86	101.15	70.88	115.26	152.58	72.53	175.56	128.98
RK-8203	17.90	21.87	19.25	30.64	22.42	61.67	66.88	69.66	90.98	72.29	120.32	120.69	100.15	176.62	129.45
RK-8301	25.00	15.23	31.21	21.72	23.29	63.32	40.25	83.31	74.67	65.39	125.67	58.01	98.65	121.71	101.01
RK-8302	26.00	20.91	27.33	28.11	25.59	69.26	69.67	66.87	88.90	73.68	170.23	110.11	170.25	110.10	140.17
Varuna	38.10	31.00	41.00	45.94	39.01	120.11	77.55	125.21	140.11	115.75	240.11	159.20	240.32	242.23	220.47
Mean	25.99	31.76	27.01	29.03		80.51	96.77	73.86	90.16		147.83	175.24	127.91	156.57	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5% (50)	C.D. at 5% (70)	C.D. at 5% (90)
Fertiliser treatment (F)	1.98	5.31	7.17
Variety (V)	3.13	8.39	11.34
F x V	6.26	16.78	22.67

At all the three stages, treatment $N_{60}P_{30}$ gave significantly highest value. At 50d, minimum fresh weight was noted with $N_{60}P_{20}$, being at par with $N_{90}P_{20}$, while at 70 and 90d, the treatment $N_{90}P_{20}$ produced significantly lowest value.

Variety Varuna performed best at all the stages of growth and significantly differed from other varieties. At 50d, the poorest performance was given by RK-8203, being at par with RK-8202, and RK-8301. At 70d, the minimum value was noted in RK-8301, which was equal to RK-8202, RK-8203 and RK-8302. At 90d, RK-8301 gave significantly minimum value.

Regarding interactions, significant maximum value was given by $N_{60}P_{30}$ X RK-1467 at all the three stages of growth; but at 50d,and 90d the value was equal to those of $N_{90}P_{30}$ X Varuna and $N_{60}P_{30}$ X PR-18 respectively. Minimum fresh weight at 50d was produced by $N_{60}P_{30}$ X RK-8301 and was equalled by $N_{90}P_{20}$ X RK-8202, $N_{60}P_{20}$ X RK-8203, $N_{60}P_{20}$ X RK-8202, $N_{90}P_{20}$ X RK-8203 and $N_{60}P_{30}$ X RK-8302. At 70 and 90d, $N_{60}P_{30}$ X RK-8301 and $N_{90}P_{20}$ X RK-8202 (being equal) produced minimum fresh weight.

4.1.1.4 Dry weight/plant

The effect of fertiliser treatment and varietal response were significant at all stages of growth. However, interaction effect was significant only at 50 and 70d of growth stages (Table 10).

Table 10: Effect of selected combinations of nitrogen and phosphorus on dry weight/plant (g) of ten varieties of mustard.

Varieties	Sampling days after sowing														
	50					70					90				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	3.30	4.11	2.80	2.79	3.25	10.50	13.71	6.29	6.56	9.27	18.99	24.67	12.60	17.69	18.49
Pusa Bold	3.05	3.11	3.08	3.49	3.18	11.10	12.40	10.00	10.83	11.08	18.06	18.67	13.37	18.69	17.19
PR-18	2.33	4.89	2.56	3.08	3.22	7.01	14.69	6.13	10.13	9.49	12.50	30.12	12.16	18.58	18.34
RK-1467	2.61	5.30	2.83	2.44	3.29	7.43	16.01	6.76	7.15	9.34	12.96	32.36	12.69	12.37	17.59
RK-8201	2.94	4.11	2.72	2.50	3.07	7.74	11.09	6.52	7.66	8.25	13.78	25.41	12.35	12.79	16.08
RK-8202	2.05	2.58	1.99	3.49	2.53	6.37	7.13	4.97	11.25	7.43	12.01	17.69	7.05	18.61	13.84
RK-8203	2.09	2.44	2.44	2.94	2.48	6.56	7.01	7.00	9.31	7.47	12.58	13.23	10.19	18.27	13.57
RK-8301	2.49	1.72	3.40	2.66	2.57	6.69	5.83	9.31	7.58	7.35	13.10	6.05	11.36	12.59	10.78
RK-8302	2.58	2.28	2.94	2.79	2.65	7.36	7.18	7.07	9.09	7.68	18.11	12.18	18.01	12.36	15.17
Varuna	4.27	3.00	4.50	4.80	4.14	13.69	8.03	13.61	15.14	12.62	25.30	17.52	25.11	25.81	23.44
Mean	2.77	3.35	2.93	3.09		8.45	10.31	7.77	9.47		15.74	19.79	13.49	16.78	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Fertiliser treatment (F)	0.23	0.92	2.96
Variety (V)	0.36	1.45	4.68
F x V	0.73	2.91	N.S.

N.S.. Non-significant

At all stages, treatment $N_{60}P_{30}$ produced maximum dry matter. All the values differed critically from each other at these stages, except at 70d where the values recorded for $N_{60}P_{30}$ and $N_{90}P_{30}$ were at par. The minimum value for dry weight at 50d was given by $N_{60}P_{20}$ but was equalled by $N_{90}P_{20}$. At 70 and 90d, the minimum value was noted in $N_{90}P_{20}$. However, it did not differ critically from $N_{60}P_{20}$.

Varuna surpassed other varieties and gave significantly highest value at all the stages of growth. At 50d, RK-8203 gave poorest performance but was equalled by RK-8202, RK-8301 and RK-8302. At 70 and 90d, the minimum value was given by RK-8301. However, its value was equalled by RK-8202, RK-8203, RK-8302 at 70d and by RK-8201 ., . RK-8203, RK-8202 and RK-8302 at 90d.

Regarding interactions, $N_{60}P_{30}$ X RK-1467 gave maximum value at 50d; but was equalled by $N_{60}P_{30}$ X PR-18 and $N_{90}P_{30}$ X Varuna. At this stage, the minimum value was noted with $N_{60}P_{30}$ X RK-8301, being at par with $N_{90}P_{20}$ X RK-8202, $N_{60}P_{20}$ X RK-8202, $N_{60}P_{20}$ X RK-8203, $N_{60}P_{30}$ X RK-8302, $N_{60}P_{20}$ X PR-18, $N_{60}P_{30}$ X RK-8203, $N_{90}P_{30}$ X RK-1467 and $N_{90}P_{20}$ X RK-8203. At 70d, the maximum value was recorded in $N_{60}P_{30}$ X RK-1467, but was at par with those for $N_{90}P_{30}$ X Varuna, $N_{60}P_{30}$ X PR-18, $N_{60}P_{30}$ X KRV-47, $N_{60}P_{20}$ X Varuna and $N_{90}P_{20}$ X Varuna. The minimum value at this stage was given by $N_{90}P_{20}$ X RK-8202 which was statistically equall to more than half of the interactions.

4.1.2 Net assimilation rate (NAR)

Net assimilation rate was significantly affected by the treatments. Varietal response and interactions were also found significant at both the intervals, i.e., 50-70 and 70-90d (Table 11).

At both the intervals, $N_{60}P_{30}$ and $N_{60}P_{20}$ (being at par) gave maximum value. The minimum value for NAR at both the intervals was given by $N_{90}P_{30}$, which was statistically equal to that of $N_{90}P_{20}$.

Regarding varietal response, Varuna gave maximum value for NAR but was at par with Pusa Bold at both the intervals. RK-8201 gave minimum value at 50-70d interval. The value was statistically equal to those for RK-8202 and RK-8301. At the later interval, (70-90d), RK-8202 gave minimum NAR value and differed critically with the rest of the varieties, except KRV-47.

Considering interaction effect, maximum value at 50-70d was recorded in $N_{60}P_{30}$ X RK-1467. The value given by this interaction was statistically equal to those of $N_{60}P_{30}$ X PR-18, $N_{90}P_{20}$ X Varuna, $N_{60}P_{20}$ X Varuna and $N_{60}P_{20}$ X KRV-47. At this interval, minimum value was given by $N_{90}P_{30}$ X RK-8201.and was equalled by $N_{60}P_{30}$ X RK-8301 and $N_{90}P_{20}$ X RK-8202. At the later interval, 70-90d, $N_{90}P_{30}$ X Varuna gave maximum value and it was statistically equal to those of $N_{90}P_{20}$ X Pusa Bold and

Table 11: Effect of selected combinations of nitrogen and phosphorus on net assimilation rate ($\times 10^{-3}$ $g/cm^2/d$) of ten varieties of mustard.

Varieties	Days intervals									
	50 - 70d					70 - 90d				
	Fertiliser treatments									
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	8.91	7.50	6.81	6.01	7.31	5.46	5.33	4.39	3.95	4.78
Pusa Bold	8.46	7.53	8.64	7.98	8.15	6.92	5.95	7.23	6.22	6.58
PR-18	6.37	9.49	6.25	7.27	7.35	5.09	7.12	5.01	5.35	5.64
RK-1467	7.31	9.73	7.03	6.27	7.59	5.91	6.76	5.35	4.55	5.64
RK-8201	7.15	6.88	6.80	4.94	6.44	6.85	5.98	6.21	4.31	5.84
RK-8202	6.05	7.01	5.91	6.88	6.46	4.97	5.88	3.17	4.03	4.51
RK-8203	6.86	7.65	7.50	7.96	7.49	4.27	5.57	4.94	5.98	5.19
RK-8301	6.34	5.72	7.49	6.77	6.58	5.46	4.21	6.04	5.22	5.23
RK-8302	7.08	7.39	6.69	7.79	7.24	5.76	5.81	4.98	5.99	5.64
Varuna	9.14	7.31	9.28	7.89	8.41	6.59	5.47	6.82	7.92	6.70
Mean	7.37	7.62	7.24	6.98		5.73	5.81	5.41	5.35	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%
Fertiliser treatment (F)	0.31	0.28
Variety (V)	0.49	0.44
F x V	0.98	0.88

$N_{60}P_{30}$ X PR-18. At this stage, the interactions $N_{90}P_{20}$ X RK-8202, $N_{90}P_{30}$ X KRV-47 and $N_{90}P_{30}$ X RK-8202 (being statistically equal) gave minimum NAR values.

4.1.3 Yield characteristics

The effect of basal treatment, varietal response as well as interaction effect was found significant for all yield parameters studied. However, the interaction effect for seeds/pod was not significant. The data are presented in Tables 12-13 and are described briefly below:

4.1.3.1 Pods/plant

Fertiliser treatment significantly affected pods/plant, $N_{60}P_{20}$ giving significantly highest number of pods. The treatment $N_{90}P_{20}$ produced minimum pods. The value given by this treatment was statistically equal to that of $N_{60}P_{30}$ and $N_{90}P_{30}$.

The variety Varuna differed critically from other varieties in this respect and produced maximum number of pods. The minimum number of pods was given by RK-8203 which differed critically from all other varieties.

With regard to interactions, $N_{90}P_{30}$ X Varuna resulted in the production of significantly maximum pods. The minimum pods were noted with $N_{60}P_{30}$ X RK-8302. This interaction was statistically equal to $N_{90}P_{20}$ X RK-8202, $N_{60}P_{20}$ X RK-8203 and $N_{60}P_{30}$ X RK-8301 (Table 12) in pod production.

Table 12: Effect of selected combinations of nitrogen and phosphorus on pods/plant, seeds/pod and necto -litre weight (kg) of ten varieties of mustard.

Varieties	Pods/plant					Seeds/pod					Hecto -litre weight				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}N_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	205.83	175.11	134.34	129.99	161.32	12.15	13.12	13.36	13.78	13.10	64.00	65.33	64.50	62.85	64.17
Pusa Bold	202.50	166.45	246.17	168.67	195.95	10.67	12.18	11.63	10.72	11.30	65.50	66.00	64.37	67.40	65.82
PR-18	171.22	216.83	167.67	201.22	189.24	13.70	12.16	12.74	10.68	12.32	63.33	63.22	66.28	64.56	64.35
RK-1467	213.50	222.11	198.74	151.17	196.38	11.59	13.86	12.08	10.43	11.99	66.11	65.50	64.00	64.00	64.90
RK-8201	168.74	156.67	135.84	132.67	148.48	12.11	11.94	12.23	12.54	12.21	66.12	63.09	64.00	64.00	64.30
RK-8202	125.56	181.18	101.33	205.89	153.49	12.13	12.65	12.73	12.77	12.57	65.10	67.36	63.31	66.16	65.48
RK-8203	110.57	146.63	135.65	152.67	136.38	13.05	11.74	13.00	13.07	12.72	64.53	63.02	63.86	66.36	64.44
RK-8301	152.89	113.11	180.94	140.33	146.82	10.52	11.83	12.88	12.00	11.81	65.22	65.09	64.50	66.00	65.20
RK-8302	183.83	100.83	161.50	179.78	156.49	12.11	10.49	12.02	10.99	11.40	64.50	67.19	65.40	63.43	65.13
Varuna	233.67	220.33	234.85	261.00	237.46	13.38	13.80	14.41	13.48	13.77	65.37	67.40	66.32	65.09	66.05
Mean	176.83	169.92	169.70	172.33		12.14	12.38	12.71	12.05		65.24	65.30	64.99	64.68	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	Pods/plant C.D. at 5%	Seeds/pod C.D. at 5%	Hecto-litre weight C.D. at 5%
Fertiliser treatment (F)	4.45	0.62	0.17
Variety (V)	7.03	0.98	0.27
F x V	14.06	N.S.	0.54

N.S. Non-significant

4.1.3.2 Seeds/pod

The effect of fertiliser treatments, though significant, was not very marked. The treatments $N_{90}P_{20}$, $N_{60}P_{30}$ and $N_{60}P_{20}$, being at par, produced maximum seeds/pod. The minimum number of seeds were produced in the treatment $N_{90}P_{30}$, the value of which was statistically equal to those for $N_{60}P_{20}$ and $N_{60}P_{30}$.

Regarding varietal response, maximum number of seeds/pod was recorded in Varuna which critically differed from the rest of the varieties, except KRV-47. The poorest response with regard to this parameter was given by Pusa Bold. The number of seeds/pod given by this variety was equal to those in RK-8302, RK-8301, RK-1467 and RK-8201.

4.1.3.3 Hecto-litre weight

Treatments, varieties and their interaction significantly affected hecto-litre weight (Table 12).

Treatments $N_{60}P_{30}$ and $N_{60}P_{20}$, being statistically equal, gave maximum value for hecto-litre weight. Treatment $N_{90}P_{30}$ gave significantly minimum value.

Among varieties, Varuna gave maximum value and differed critically from all other varieties, except Pusa Bold. The minimum value was given by KRV-47. The value given by this variety was statistically equal to those for RK-8201, PR-18 and RK-8203.

Regarding interactions, $N_{90}P_{30}$ X Pusa Bold gave maximum value. The value recorded in this interactions was at par with those for $N_{60}P_{30}$ X Varuna, $N_{60}P_{30}$ X RK-8202 and $N_{60}P_{30}$ X RK-8302. Minimum value for this parameter was recorded in $N_{90}P_{30}$ X KRV-47. However, the value was statistically equal to those for $N_{60}P_{30}$ X RK-8203, $N_{60}P_{30}$ X RK-8201, $N_{60}P_{30}$ X PR-18, $N_{90}P_{20}$ X RK-8202 and $N_{60}P_{20}$ X PR-18.

4.1.3.4 <u>Seed Yield</u>

The effect of treatment, variety and their interaction was significant (Table 13).

Treatment $N_{60}P_{30}$ gave maximum value, which differed critically from other treatments, except $N_{60}P_{20}$. The minimum value was recorded with $N_{90}P_{30}$ and $N_{90}P_{20}$ which were statistically equal.

Pertaining to varieties, Varuna gave significantly maximum seed yield. The poorest performance was shown by RK-8203, the value of which was at par with those for RK-8302, RK-8301 and RK-8202.

The interactions $N_{60}P_{30}$ X PR-18, $N_{60}P_{30}$ X RK-1467 and $N_{90}P_{30}$ X Varuna, being at par, gave maximum value. The interaction $N_{60}P_{30}$ X RK-8301 gave minimum value and differed critically from all other interactions, except $N_{90}P_{30}$ X RK-8302.

Table 13: Effect of selected combinations of nitrogen and phosphorus on seed yield (kg/ha), oil content (%) and oil yield (kg/ha) of ten varieties of mustard.

Varieties	Seed yield					Oil content					Oil yield				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	1016.99	876.67	821.33	782.89	874.47	41.42	37.42	35.13	33.08	36.76	421.14	328.37	288.56	259.28	324.34
Pusa Bold	916.09	864.67	938.67	902.22	905.41	33.30	33.48	33.19	38.50	34.62	305.06	289.76	311.63	347.46	313.48
PR-18	750.45	1253.67	725.22	881.78	902.78	38.00	36.89	39.52	35.28	37.42	285.15	462.42	286.76	310.97	336.33
RK-1467	898.45	1240.00	871.33	651.11	915.22	34.90	37.35	31.50	37.82	35.39	313.78	463.14	274.56	246.23	324.43
RK-8201	916.00	902.20	806.33	674.67	824.80	34.60	39.35	32.74	27.39	33.52	316.52	155.52	263.78	184.92	280.19
RK-8202	677.66	799.67	658.67	903.11	759.78	37.22	40.48	31.20	25.52	33.60	252.27	323.65	206.12	230.29	253.08
RK-8203	632.56	797.78	715.55	668.00	753.47	32.13	41.89	38.04	43.40	38.87	203.12	334.09	272.27	276.71	296.55
RK-8301	838.00	536.00	946.56	710.00	757.14	30.28	29.83	27.70	37.47	31.32	253.40	159.94	262.19	266.13	235.42
RK-8302	936.03	680.55	766.22	583.78	741.65	40.56	36.38	36.73	38.50	38.04	379.65	246.43	281.34	224.76	283.05
Varuna	1036.67	856.67	1061.53	1224.00	1044.72	41.40	35.83	35.91	36.59	37.43	429.27	307.12	381.14	447.57	391.28
Mean	861.69	880.79	831.14	818.16		36.38	36.89	34.17	35.35		315.94	327.04	282.84	289.43	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	Seed yield C.D. at 5%	Oil content C.D. at 5%	Oil yield C.D. at 5%
Fertiliser treatment (F)	19.55	0.91	16.96
Variety (V)	30.89	1.44	26.82
F X V	61.78	2.88	53.64

4.1.3.5 Oil content

Oil content was significantly affected by treatments. Varietal response and interaction effect were also significant (Table 13).

Maximum oil content was noted with $N_{60}P_{30}$ which differed critically from other treatments except $N_{60}P_{20}$. Treatment $N_{90}P_{20}$ gave significantly lowest value.

Regarding varieties, RK-8203 gave maximum value. However, the value was equalled by RK-8302 and Varuna. Variety RK-8301 gave significantly lowest value for oil content.

With regard to interaction effect, $N_{90}P_{30}$ X RK-8203 gave maximum value which was statistically equal to those for $N_{60}P_{30}$ X RK-8203, $N_{60}P_{20}$ X KRV-47, $N_{60}P_{20}$ X Varuna and $N_{60}P_{20}$ X RK-8302. The minimum value was recorded in the interactions $N_{90}P_{30}$ X RK-8202, $N_{90}P_{30}$ X RK-8201 and $N_{90}P_{20}$ X RK-8301 which were at par.

4.1.3.6 Oil yield

The effect of treatment, varietal response and their interaction on oil yield was found significant (Table 13).

$N_{60}P_{30}$ and $N_{60}P_{20}$, being at par, produced maximum oil/ha. The minimum value was noted for $N_{90}P_{20}$ which was at par with $N_{90}P_{30}$.

Varuna gave significantly highest value. The minimum value for oil yield was given by RK-8301 which differed critically from all other varieties except RK-8202.

Regarding interaction, $N_{60}P_{30}$ X RK-1467 gave maximum value which was at par with $N_{60}P_{30}$ X PR-18, $N_{90}P_{30}$ X Varuna, $N_{60}P_{20}$ X Varuna and $N_{60}P_{20}$ X KRV-47. The minimum value was given by $N_{60}P_{30}$ X RK-8301. Its effect was statistically equal to those of $N_{90}P_{30}$ X RK-8201, $N_{60}P_{20}$ X RK-8203 and $N_{90}P_{20}$ X RK-8202.

4.1.4 Quality characteristics

The effect of fertiliser treatment, varietal response and interaction was found significant for all parameters studied to assess the quality of oil, except the effect of fertiliser treatment, interaction effect on acid value which were found non-significant. The data are presented in Table 14 and are described briefly below. It may be added that low acid and iodine values are considered good for storage and hydrogenation respectively and high saponification value is regarded good for digestibility and soap making.

4.1.4.1 Acid value

As mentioned earlier, the effect of fertiliser treatment on this parameter was found non-significant.

Varieties RK-8201 and KRV-47, giving statistically equal value, showed minimum acid value. On the other hand varieties RK-8301, Varuna, RK-8202 and RK-8203, being at par, gave maximum acid value.

Table 14: Effect of selected combinations of nitrogen and phosphorus on acid value, iodine value and saponification value of ten varieties of mustard.

Varieties	Acid value					Iodine value					Saponification value				
	Fertiliser treatments														
	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{90}P_{20}$	$N_{90}P_{30}$	Mean
KRV-47	2.81	2.81	2.62	2.99	2.81	106.34	106.14	105.64	105.33	105.86	173.49	172.63	172.16	170.43	172.18
Pusa Bold	2.99	3.37	3.93	2.81	3.28	103.29	105.07	105.72	106.93	105.25	176.87	171.81	175.23	170.63	173.64
PR-18	2.81	2.99	3.30	2.99	3.02	106.09	106.09	104.63	105.07	105.47	178.49	175.41	175.16	172.96	175.51
RK-1467	2.81	2.81	3.74	2.43	2.95	105.33	105.78	102.28	105.07	104.62	179.49	176.08	175.45	170.90	175.48
RK-8201	2.43	2.43	2.43	3.18	2.62	106.53	105.67	106.34	107.48	106.51	176.80	176.32	172.16	170.48	173.94
RK-8202	3.36	3.92	5.05	3.50	3.96	105.33	103.29	105.07	105.62	104.83	178.97	176.34	176.84	176.02	177.04
RK-8203	3.98	3.50	3.69	3.79	3.74	105.66	104.53	104.31	104.31	104.70	176.61	174.94	173.61	171.99	174.29
RK-8301	4.60	3.76	4.19	4.60	4.29	104.63	105.07	106.55	104.06	105.08	177.66	176.99	176.47	174.95	176.52
RK-8302	3.92	3.96	3.81	4.07	3.94	104.18	103.65	105.33	101.19	103.59	175.44	174.86	174.76	173.52	174.65
Varuna	4.42	4.02	4.47	4.08	4.25	104.65	102.28	103.28	102.72	103.23	180.17	178.94	178.80	175.12	178.26
Mean	3.41	3.36	3.72	3.44		105.20	104.76	104.92	104.78		177.39	175.43	175.06	172.70	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Fertiliser treatment (F)	N.S.	0.15	0.89
Variety (V)	0.52	0.24	1.41
F x V	N.S.	0.47	2.81

N.S. Non-significant

4.1.4.2 Iodine value

The effect of treatments, varietal response and their interaction was found significant.

The minimum value was noted with $N_{60}P_{30}$ which differed critically from all other treatments, except $N_{90}P_{30}$. Treatment $N_{60}P_{20}$ gave significantly maximum value.

Variety Varuna gave significantly lowest iodine value and variety RK-8201 gave maximum value and differed significantly from the others.

Regarding interaction, $N_{90}P_{30}$ X RK-8302 and $N_{90}P_{30}$ X RK-8201 gave significantly minimum and maximum values respectively.

4.1.4.3 Saponification value

Treatments significantly affected saponification value. Varietal response and interaction effect were also significant.

Treatments $N_{60}P_{20}$ and $N_{90}P_{30}$ gave significantly highest and lowest values respectively.

Regarding varieties, Varuna gave maximum value which critically differed from others, except RK-8202. Variety KRV-47 gave significantly lowest value.

As far as interaction effects were concerned, $N_{60}P_{20}$ X Varuna gave maximum value which was at par with those for $N_{60}P_{20}$X RK-1467, $N_{60}P_{20}$ X RK-8202, $N_{60}P_{30}$ X Varuna, $N_{90}P_{20}$ X Varuna, $N_{60}P_{20}$ X PR-18 and $N_{60}P_{20}$ X RK-8301. The minimum value was noted for $N_{90}P_{30}$ X KRV-47 which differed significantly from most of the other interactions.

4.2 Experiment 2

In a simple randomised field trial, the effect of pre-sowing seed treatment with graded pyridoxine solution was studied on growth, net assimilation rate (NAR), leaf NPK content, oil content, seed and oil yield and quality characteristics of oil of mustard (*Brassica juncea* L. Czern.& Coss). var. Varuna that proved most superior in the varietal trial (Experiment 1). The data are described below and summarised in Table 15-20.

4.2.1 Growth characteristics

Growth characters were studied at three stages of growth, 50, 70 and 90d after sowing, corresponding to vegetative, flowering and fruiting. The parameters studied were shoot length, root length, leaf number, fresh weight and dry weight. All parameters were significantly affected by the treatment at the three stages (Table 15-17).

4.2.1.1 Shoot length/plant

Treatment 0.05% produced tallest plants at all the three stages (Table 15). This treatment differed critically from the

Table 15: Effect of pre-sowing seed treatment with pyridoxine on shoot length/plant (cm) and root length/plant (cm) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Shoot length/plant			Root length/plant		
	Sampling days after sowing					
	50	70	90	50	70	90
Water-soaked control	68.33	98.53	134.18	7.66	10.90	13.42
0.05	76.75	108.84	140.33	9.26	13.00	17.52
0.10	72.29	108.72	137.04	8.86	12.45	15.29
0.20	69.22	105.17	136.09	8.22	11.19	14.49
C.D. at 5%	2.58	5.73	2.46	0.43	0.61	2.50

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

others at all stages except at 70d, when its effect was at par with those of 0.1 and 0.2%. The increase in shoot length due to 0.05% was 12.3, 10.5 and 4.6% at 50, 70 and 90d in comparison to the respective water-soaked controls. Shortest plants were produced by the control which differed critically from all other treatments, except 0.2% at 50 and 90d.

4.2.1.2 Root length/plant

Pyridoxine treatment of seeds significantly affected root length at all the three stages of growth (Table 15), 0.05% giving maximum value and differing critically from the other treatments,except 0.10%. Treatment 0.05% enhanced root length by 20.9, 19.3 and 30.5% at 50, 70 and 90d in comparison to their respective controls. Significant lowest value was given by the control at 50d. At 70 and 90d also, control gave minimum value but was statistically equal to 0.2%; and 0.2% and 0.1% respectively.

4.2.1.3 Leaf number/plant

The maximum value was recorded in 0.05% at all the stages and it differed critically from other treatments, except 0.1% at 70 and 90d. The increase in leaf number due to 0.05% was 33.2, 19.3 and 38.9%, over control at 50, 70 and 90 d respectively. The highest concentration (0.2%) gave significantly lowest value at 50 and 70d. But at 90d, minimum value was noted in the control. However, it was at par with 0.2% (Table 16).

Table 16: Effect of pre-sowing seed treatment with pyridoxine on leaf number/plant and fresh weight/plant (g) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Leaf number/plant			Fresh weight/plant		
	Sampling days after sowing					
	50	70	90	50	70	90
Water-soaked control	9.77	14.88	21.92	28.45	34.38	90.52
0.05	13.01	17.75	30.45	40.44	50.96	128.49
0.10	9.91	17.09	29.11	38.24	48.69	108.33
0.20	8.48	12.89	22.47	30.55	38.54	103.69
C.D. at 5%	1.08	0.87	2.72	3.75	2.07	10.89

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

4.2.1.4 Fresh weight/plant

Treatment 0.05% gave significant maximum value at all the stages, except 50d when its effect was at par with that of 0.1%. The increase in fresh weight in 0.5% was 42.1, 48.2 and 41.9% over the controls at 50, 70 and 90d respectively. The minimum value was given by control at all the stages and it differed critically from the other treatments, except 0.2% at 50d (Table 16).

4.2.1.5 Dry weight/plant

Treatment 0.05% produced maximum dry matter and the value differed critically from those for other treatments at all the three stages of growth. The increase was 55.0, 40.7 and 42.2% in comparison with controls at 50, 70 and 90d respectively. Treatment 0.2% gave minimum value at 50d but was statistically equal with 0.1% and control. At 70 and 90d, the minimum value was noted in the control which differed critically from other treatments at 90d. However, at 70d, the value of the control was at par with those of 0.2% and 0.1% (Table 17).

4.2.2 Net assimilation rate (NAR)

The maximum significant value for NAR at both intervals (50-70d and 70-90d) was given by 0.05%. The increase due to this treatment was 45.9 and 24.1% in comparison with controls at 50-70d and 70-90d respectively. At the first interval (50-70d),

Table 17: Effect of pre-sowing seed treatment with pyridoxine on dry weight/plant (g) and net assimilation rate ($x10^{-3}$ g/cm^2/d) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Dry weight/plant			Net assimilation rate	
	Sampling days after sowing			Days interval	
	50	70,	90	50-70	70-90
Water-soaked control	3.11	5.72	22.63	5.38	4.19
0.05	4.82	8.05	32.17	7.85	5.20
0.10	2.78	6.37	27.09	6.67	4.64
0.20	2.56	6.11	25.96	5.64	3.52
C.D. at 5%	1.38	1.67	3.11	0.61	0.49

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

the minimum value was noted in the control which was at par with 0.2%. At the later interval (70-90d), 0.2% gave significantly lowest value (Table 17).

4.2.3 Leaf NPK content

The effect of seed treatment on leaf NPK contents was significant at all the stages of growth. The data are briefly described below and are presented in Table 18.

4.2.3.1 Nitrogen

Treatment 0.05% gave significant maximum value of nitrogen content in leaves at all the three stages. The increase in nitrogen content was 35.0, 28.0 and 41.9% over the controls at 50, 70 and 90d respectively. Significant lowest value was given by 0.2% at all the three stages, except 0.1% at 70d and the control and 0.1% at 90d.

4.2.3.2 Phosphorus

The maximum value was given by 0.05% which differed critically from other treatments at all the three stages. The increase in phosphorus content was 30.6, 19.4 and 14.3% in comparison with the controls at 50, 70 and 90d respectively. The lowest value was given by 0.2% at all the three stages. However, at 50d, the value for this treatment was at par with those for the control and 0.1%, whereas, it was statistically equal with 0.1% at 70 and 90d.

Table 18: Effect of pre-sowing seed treatment with pyridoxine on nitrogen content (%), phosphorus content (%) and potassium content (%) in leaves of mustard variety Varuna.

Seed treatments (% pyridoxine)	Nitrogen			Phosphorus			Potassium		
	Sampling days after sowing								
	50	70	90	50	70	90	50	70	90
Water-soaked control	4.14	3.79	3.15	0.36	0.31	0.28	4.15	3.67	2.59
0.05	5.59	4.85	4.47	0.47	0.37	0.32	5.45	4.15	3.53
0.10	4.18	3.64	3.29	0.36	0.27	0.21	4.67	3.77	2.96
0.20	3.23	3.06	2.72	0.33	0.25	0.21	4.45	3.33	2.45
C.D. at 5%	0.17	0.72	0.62	0.03	0.05	0.02	0.27	0.29	0.10

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

4.2.3.3 Potassium

Treatment 0.05% again gave significant maximum value of potassium content at all the three stages. The increase was 31.3, 13.1 and 36.3% over controls at 50, 70 and 90d respectively. Significantly lowest value was given by the control at 50d, and 0.2% at 70 and 90d.

4.2.4 Yield characteristics

All yield parameters were significantly affected by the pyridoxine seed treatment. The data are presented in Table 19 and are described briefly below:

4.2.4.1 Pods/plant

Treatment 0.05% gave maximum value and differed critically in its effect from all other treatments. The increase in number of pods due to 0.05% pyridoxine was 26.4% over control. The minimum value was given by the control; but it was statistically equal with those for 0.2% and 0.10%.

4.2.4.2 Seeds/pod

Seed number also was maximum in 0.05%. However, its effect was statistically equal with that of 0.1%. There was 4.9% increase over the control due to this treatment. The minimum seed number was noted in the control but the value was at par with that in 0.2%.

Table 19: Effect of pre-sowing seed treatment with pyridoxine on pods/plant, seeds/pod, hecto-litre weight (kg), seed yield (kg/ha), oil content (%) and oil yield (kg/ha) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Pods/plant	Seeds/pod	Hecto-litre weight	Seed yield	Oil content	Oil yield
Water-soaked control	162.92	12.83	63.83	708.67	34.73	245.20
0.05	205.87	13.46	66.17	806.22	36.00	286.21
0.10	181.20	13.21	65.33	742.63	38.07	278.48
0.20	174.71	13.10	65.00	731.00	34.08	246.71
C.D. at 5%	23.59	0.34	0.57	27.13	0.22	9.61

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

4.2.4.3 Hecto-litre weight

Treatment 0.05% gave significant, maximum value for hecto-litre weight which was increased by 3.7% in comparison with the control. The minimum value was recorded in the control which differed significantly with other treatments.

4.2.4.4 Seed yield

Maximum seed yield was noted in 0.05% treatment which differed critically from all other treatments in this respect. The increase in seed yield was 13.8% over the control. The minimum value was recorded in the control; but it was statistically equal to that in treatment 0.2%.

4.2.4.5 Oil content

Treatment 0.10% gave significant maximum value for the oil percentage in seeds. Treatment 0.05% was next to 0.10% in this respect. The increase in oil content due to 0.10 and 0.05% treatments was 9.6 and 3.7% over the control respectively. Significant lowest value was given by 0.20% pyridoxine treatment.

4.2.4.6 Oil yield

Treatments 0.05 and 0.10%, being statistically equal gave maximum value for oil yield. There was 16.7% increase over the control due to 0.05%. Minimum value was obtained in the control which differed critically from other treatments, except 0.2%.

4.2.5 Quality characteristics

Treatments significantly affected all parameters of oil quality, except acid value. The data are presented in Table 20 and are described briefly below:

4.2.5.1 Acid value

As mentioned earlier, all pre-sowing seed treatments effected acid value equally.

4.2.5.2 Iodine value

The lowest iodine value was noted in the control which was at par with 0.2%. The effect was 3.4% less than of 0.05% treatment which gave significantly maximum value.

4.2.5.3 Saponification value

The significant highest and lowest value was obtained in 0.05% and 0.2% respectively. The increase due to 0.05% was 24.7% in comparison with the control.

4.3 Experiment 3

A factorial randomised field trial was conducted to study the effect of pre-sowing seed treatment with pyridoxine and three combinations of basally applied nitrogen and phosphorus on growth, net assimilation rate (NAR), leaf NPK contents, oil content of seed, yield of seed and oil and quality characteristics

Table 20: Effect of pre-sowing seed treatment with pyridoxine on acid value, iodine value and saponification value of mustard variety Varuna.

Seed treatments (% pyridoxine)	Acid value	Iodine value	Saponification value
Water-soaked control	2.81	103.12	130.51
0.05	3.37	106.68	162.69
0.10	2.62	105.44	159.70
0.20	3.55	103.89	116.54
C.D. at 5%	N.S.	0.95	0.37

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

of oil mustard var. Varuna. Since unsoaked and water-soaked controls were at par for all parameters studied, the increase due to treatment was compared with water-soaked control. The data are described below and are summarised in Tables 21-32.

4.3.1 Growth characteristics

All parameters studied were found significantly affected by seed treatment, fertiliser treatment and their interactions at 50, 70 and 90d of growth, except the effect of fertiliser treatment on leaf number at 90d and the effects of all variants on root length at 90d. The data are summarised in Tables 21-25 and are described briefly below:

4.3.1.1 Shoot length/plant

The effect of seed treatment, fertiliser treatment and of their interaction was found significant at all the three stages of growth (Table 21).

Seed treatment 0.025% gave significant maximum value at all the three stages, except 90d, when its effect was at par with that of 0.0125%. The increase in shoot length due to 0.025% was 40.3, 45.9 and 15.7% over the control at 50, 70 and 90d respectively. The shortest plants were produced by 0.10% at 50 and 90d. However, the value was statistically equal to those for unsoaked and water-soaked controls at 50d and water-soaked control at 90d. Moreover, at 70d, unsoaked control gave minimum value and differed

Table 21: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on shoot length/plant (cm) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	42.65	55.30	44.72	47.56	62.85	87.91	65.04	71.93	106.59	110.49	106.79	107.96
Water-soaked control	45.11	53.33	46.33	48.26	68.14	95.85	64.59	76.19	105.19	105.84	98.18	103.07
0.0125	52.36	65.55	61.36	59.76	98.78	103.61	107.93	103.44	109.40	116.53	109.24	111.72
0.025	69.19	68.06	65.93	67.73	108.79	113.89	110.93	111.20	112.37	125.23	120.01	119.20
0.05	50.29	52.36	48.01	50.22	100.71	96.50	90.78	95.99	103.65	108.28	116.82	109.58
0.10	43.78	49.18	45.64	46.20	67.00	86.32	73.08	75.47	92.33	100.24	99.31	97.29
Mean	50.56	57.49	51.99		84.38	97.35	85.39		104.92	111.10	108.39	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	3.02	5.94	7.45
Fertiliser treatment (F)	2.18	4.28	5.38
S x F	5.23	10.28	12.90

critically from other treatments, except 0.10% and water-soaked control.

Regarding fertiliser treatment, $N_{90}P_{30}$ gave significant maximum value at all the stages except at 90d, when its effect was at par with that of $N_{60+30}P_{30}$. The minimum value was given by $N_{60}P_{20}$ which was statistically equal with that of $N_{60+30}P_{30}$ at all the stages.

The interaction 0.025 X $N_{60}P_{20}$ gave maximum value at 50d which was statistically equal to those for 0.025 X $N_{90}P_{30}$, 0.025 X $N_{60+30}P_{30}$ and 0.0125 X $N_{90}P_{30}$. At this stage the minimum value was recorded in unsoaked control X $N_{60}P_{20}$ which was at par with those for 0.10 X $N_{60}P_{20}$, unsoaked control X $N_{60+30}P_{30}$, water-soaked control X $N_{60}P_{20}$, 0.10 X $N_{60+30}P_{30}$ and water-soaked control X $N_{60+30}P_{30}$. At 70d, 0.025 X $N_{90}P_{30}$ gave maximum value which was statistically equal with those for 0.025 X $N_{60+30}P_{30}$, 0.025 X $N_{60}P_{20}$,0.0125 X $N_{60+30}P_{30}$ and 0.0125 X $N_{90}P_{30}$. The minimum value was given by unsoaked control X $N_{60}P_{20}$ which differed critically from other interactions, except water-soaked control X $N_{60+30}P_{30}$ and unsoaked control X $N_{60+30}P_{30}$. The maximum value at 90d was recorded in 0.025 X $N_{90}P_{30}$ which was at par with those for 0.025 X $N_{60+30}P_{30}$, 0.05 X $N_{60+30}P_{30}$, 0.0125 X $N_{90}P_{30}$ and 0.025 X $N_{60}P_{20}$. The minimum value at this stage was given by 0.10 X $N_{60}P_{20}$ which was statistically equal with those for water-soaked control X $N_{60+30}P_{30}$, 0.10 X $N_{60+30}P_{30}$, 0.10 X $N_{90}P_{30}$, 0.05 X $N_{60}P_{20}$ and water-soaked control X $N_{60}P_{20}$.

4.3.1.2 Root length/plant

Seed treatment,fertiliser treatment and their interaction significantly affected root length at all the stages, except 90d (Table 22).

Treatment 0.025% gave significant maximum value at 50 and 70d stages; but at 70d it was at par with that of 0.0125%. The increase in root length due to 0.025% was 16.9 and 11.4% at 50 and 70d respectively. At both these stages, 0.10% gave significant lowest value.

Fertiliser treatments, $N_{60}P_{20}$ and $N_{60+30}P_{30}$, being statistically equal, gave maximum value at both the stages. $N_{90}P_{30}$ gave significant minimum value at both the stages; but at 70d it was statistically equal to that of $N_{60+30}P_{30}$.

Regarding interaction, 0.025 X $N_{90}P_{30}$ gave maximum value at 50d, but was statistically equal to 0.025 X $N_{60+30}P_{30}$, 0.0125 X $N_{60}P_{20}$ and 0.025 X $N_{60}P_{20}$. At this stage, minimum value was noted with 0.10 X $N_{90}P_{30}$ which differed critically from all other interactions, except 0.10 X $N_{60+30}P_{30}$ and water-soaked control X $N_{90}P_{30}$. At 70d, the interaction 0.0125 X $N_{60}P_{20}$ gave maximum value but was at par with 0.025 X $N_{90}P_{30}$. The minimum value was recorded in 0.10 X $N_{60}P_{20}$ which, however, did not differ critically from 0.10 X $N_{90}P_{30}$, 0.10 X $N_{60+30}P_{30}$, unsoaked control X $N_{90}P_{30}$, water-soaked control X $N_{90}P_{30}$ and 0.05 X $N_{90}P_{30}$.

Table 22: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on root length/plant (cm) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	12.42	11.86	12.56	12.28	14.76	13.02	14.91	14.23	15.82	14.28	14.96	14.89
Water-soaked control	12.11	11.27	12.46	11.95	14.62	13.42	14.05	14.03	15.98	14.43	14.79	15.07
0.0125	13.80	12.09	13.09	12.99	16.91	14.50	15.06	15.49	18.02	15.60	16.08	16.57
0.025	13.64	14.40	13.87	13.97	15.06	16.86	14.98	15.63	16.65	17.92	16.46	17.01
0.05	12.61	11.93	11.96	12.17	14.46	13.54	14.18	14.06	14.91	14.68	14.94	14.84
0.10	12.00	10.63	11.09	11.24	12.22	12.24	12.37	12.28	13.42	12.66	12.80	12.96
Mean	12.76	12.03	12.51		14.67	13.93	14.26		15.80	14.93	15.01	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.45	0.96	N.S.
Fertiliser treatment (F)	0.32	0.69	N.S.
S x F	0.78	1.66	N.S.

N.S. Non-significant

4.3.1.3 <u>Leaf number/plant</u>

The effect of seed treatment, fertiliser treatment and their interaction was found significant at all stages of growth. However, the effect of fertiliser treatment at 90d was non-significant (Table 23).

Seed treatment 0.025% gave significant maximum value at all the three stages of growth. This treatment increased the leaf number by 31.9 , 73.0 and 25.9 in comparison with control at 50, 70 and 90d respectively. Significant lowest value was given by 0.10% at 50 and 90d. At 70d, the minimum value was recorded with water-soaked control which was statistically equal with those for unsoaked control and 0.10%.

Significant maximum value was given by $N_{60}P_{20}$ at both the 50 and 70d stages; but, at 50d, it was at par with $N_{90}P_{30}$. Significant lowest value was recorded in $N_{60+30}P_{30}$ at both the stages.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value at 50 and 90d which differed critically from others, except 0.025 X $N_{60}P_{20}$ at 50d and 0.025 X $N_{60}P_{20}$, 0.125 X $N_{90}P_{30}$ and 0.0125 X $N_{60}P_{20}$ at 90d. At 70d maximum value was given by 0.025 X $N_{60}P_{20}$ which was statistically equal to those for 0.025 X $N_{90}P_{30}$ and 0.0125 X $N_{60}P_{20}$. At 50d, significant lowest value was given by 0.10 X $N_{60+30}P_{30}$ and, at 70d, by water-soaked control X $N_{60+30}P_{30}$ which was at par with unsoaked control X $N_{90}P_{30}$, water-soaked control X $N_{90}P_{30}$, unsoaked control X $N_{60+30}P_{30}$,

Table 23: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on leaf number/plant of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	6.33	6.00	5.67	6.00	15.33	10.67	11.33	12.44	20.33	19.56	21.56	20.48
Water-soaked control	6.67	6.30	5.97	6.31	13.67	11.33	10.07	11.69	21.67	18.32	20.11	20.03
0.0125	7.83	7.33	7.67	7.61	19.00	18.58	14.00	17.19	25.16	25.37	24.23	24.05
0.025	8.30	8.67	8.00	8.32	21.67	20.67	18.33	20.22	26.16	26.31	23.16	25.21
0.05	6.00	6.30	4.99	5.76	14.67	16.00	16.83	15.83	18.97	21.11	18.21	19.43
0.10	5.38	5.80	4.01	5.06	12.67	12.67	12.33	12.56	16.38	17.36	17.33	17.02
Mean	6.75	6.73	6.05		16.17	14.99	13.82		21.45	21.34	20.77	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.32	1.61	0.94
Fertiliser treatment (F)	0.23	1.16	N.S.
S x F	0.56	2.78	1.62

N.S. Non-significant

0.10 X $N_{60+30}P_{30}$, 0.10 X $N_{60}P_{20}$ and 0.10 X $N_{90}P_{30}$. At 90d, minimum value was given by 0.10 X $N_{60}P_{20}$ which differed critically from others, except 0.10 X $N_{60+30}P_{30}$ and 0.10 X $N_{90}P_{30}$.

4.3.1.4 Fresh weight/plant

Seed treatment, fertiliser treatment and their interaction affected fresh weight significantly at all the three stages (Table 24).

Seed treatment with 0.025% pyridoxine solution gave significantly maximum value at all the three stages, except 90d, when its effect was at par with that of 0.0125%. The increase in fresh weight due to soaking in 0.025% was 47.4, 41.7 and 48.2% over control at 50, 70 and 90d respectively. Minimum value was given by 0.10% which differed critically from other treatments at all the stages, except 90d, when it was at par with water-soaked control and unsoaked control.

The fertiliser treatment $N_{90}P_{30}$ gave maximum value at 50d. However, it was at par with that of $N_{60}P_{20}$. At 70 and 90d, $N_{60}P_{20}$ gave significant maximum value. At all the three stages $N_{60+30}P_{30}$ gave significant minimum value.

Regarding interaction, 0.025 X $N_{90}P_{30}$ gave significant maximum value at 50 and 70d, but at the later stage, when it was at par with 0.0125 X $N_{60}P_{20}$. At 90d maximum value was given by 0.0125 X $N_{60}P_{20}$ which was statistically equal to those for 0.025 X $N_{60}P_{20}$ and 0.025 X $N_{90}P_{30}$. On the other hand minimum

Table 24: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on fresh weight/plant (g) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	31.45	28.31	35.27	31.68	76.07	63.69	48.23	62.66	101.32	94.26	94.44	96.67
Water-soaked control	34.37	33.23	32.40	33.33	80.50	65.07	53.01	66.19	112.76	88.87	86.80	96.14
0.0125	49.48	42.77	40.67	44.31	104.55	80.30	61.52	82.12	175.96	119.82	104.06	133.28
0.025	45.57	55.69	46.42	49.23	99.58	112.68	69.14	93.79	165.83	163.56	98.09	142.49
0.05	38.38	38.68	36.41	37.82	88.31	73.36	56.42	73.36	142.53	92.01	87.08	107.21
0.10	27.36	30.93	27.66	28.65	65.50	72.05	31.32	56.29	128.06	70.28	69.57	89.30
Mean	37.77	38.27	36.47		85.75	78.19	53.27		137.75	104.80	90.01	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5% (50)	C.D. at 5% (70)	C.D. at 5% (90)
Seed treatment (S)	1.82	5.17	10.88
Fertiliser treatment (F)	1.29	3.66	7.69
S x F	3.16	8.95	18.84

value was recorded in 0.10 X $N_{60}P_{20}$ at 50d, which differed critically from other interations, except 0.10 X $N_{60+30}P_{30}$ and unsoaked control X $N_{60}P_{30}$. At 70 and 90d, significant lowest value was given by 0.10 X $N_{60+30}P_{30}$; but at 90d, the value given by this interaction was statistically equal to those for 0.10 X $N_{90}P_{30}$, water-soaked control X $N_{60+30}P_{30}$ and 0.05 X $N_{60+30}P_{30}$.

4.3.1.5 Dry weight/plant

Seed treatment, fertiliser treatment and of their interaction significantly affected dry matter production at all the three stages of growth (Table 25).

Seed treatments 0.025% and 0.0125%, being at par, gave maximum value at all the three stages. An increase of 36.8, 41.8 and 33.2% dry matter over the control was noted at 50, 70 and 90d respectively. Significant lowest value was given by 0.10% at 50d. However, at 70 and 90d, the effect of the same concentration being poorest was statistically equal with those for water-soaked control and unsoaked control.

Fertiliser treatment $N_{60}P_{20}$ gave maximum value at all three stages but was at par with $N_{90}P_{30}$ at 70 and 90d. Significant lowest value was given by $N_{60+30}P_{30}$ at all the three stages.

Regarding interaction effect, 0.0125 X $N_{60}P_{20}$ gave maximum value which was statistically equal to that of 0.025 X $N_{60}P_{20}$ at 50d. At 70 and 90d, maximum value was recorded in 0.025 X $N_{60}P_{30}$ which differed critically from the other

Table 25: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on dry weight/plant (g) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	4.31	4.22	3.68	4.07	13.25	10.85	11.76	11.95	18.97	16.49	17.04	17.50
Water-soaked control	4.05	4.03	3.41	3.83	12.04	11.53	12.12	11.89	17.93	15.50	18.39	17.27
0.0125	6.17	4.29	4.66	5.04	18.86	14.69	13.00	15.52	24.02	21.99	19.98	21.99
0.025	5.81	5.13	4.79	5.24	17.39	19.22	13.98	16.86	23.14	24.42	21.47	23.01
0.05	3.69	3.94	2.82	3.48	15.22	13.89	12.35	13.82	20.14	22.15	19.29	20.53
0.10	2.61	2.79	2.53	2.64	10.33	12.82	10.42	11.19	16.17	18.45	15.50	16.71
Mean	4.44	4.07	3.65		14.52	13.83	12.27		20.06	19.83	18.61	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5% (50)	C.D. at 5% (70)	C.D. at 5% (90)
Seed treatment (S)	0.29	1.43	1.11
Fertiliser treatment (F)	0.21	1.01	0.80
S x F	0.50	2.47	1.92

interactions, except 0.0125 X $N_{60}P_{20}$ and 0.025 X $N_{60}P_{20}$. Minimum value was given by 0.10 X $N_{60+30}P_{30}$ at 50 and 90d which differed critically from the other interactions, except 0.10 X $N_{60}P_{30}$, 0.10 X $N_{90}P_{30}$ and 0.05 X $N_{60}P_{30}$ at 50d, and water-soaked control X $N_{60}P_{30}$, 0.10 X $N_{60}P_{20}$ and unsoaked control X $N_{90}P_{30}$ at 90d. At 70d, minimum value was given by 0.10 X $N_{60}P_{20}$ which was at par with those for about half of the interactions.

4.3.2 Net assimilation rate (NAR)

NAR was significantly affected by seed treatment, fertiliser treatment and their interaction at both intervals, i.e., 50-70d and 70-90d (Table 26).

Seed treatments 0.025% and 0.10% gave significant maximum and minimum values respectively at both the intervals. The increase in NAR due to 0.025% over the control was 57.4 and 72.5% at 50-70d and 70-90d respectively.

$N_{60}P_{20}$ gave maximum value at both intervals and differed critically from other fertiliser treatments, except $N_{90}P_{30}$ at 50-70d. Fertiliser treatment $N_{60+30}P_{30}$ gave significant lowest value at both intervals, except at 70-90d when it was at par with $N_{90}P_{30}$.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value and was statistically equal to 0.0125 X $N_{60}P_{20}$ and $N_{60}P_{20}$ and 0.025 X $N_{60}P_{20}$ at both intervals. The minimum value was given by 0.10 X $N_{60}P_{20}$ at 50-70d and was at par with those

Table 26: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on net assimilation rate ($x10^{-3}$ $g/cm^2/d$) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Days interval							
	50-70d				70-90d			
	Fertiliser treatments							
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	5.99	4.69	4.98	5.22	4.88	3.40	3.56	3.95
Water-soaked control	5.67	5.01	5.82	5.50	4.69	2.60	4.26	3.85
0.0125	9.37	7.97	6.80	8.05	6.95	4.87	4.66	5.49
0.025	9.01	9.67	7.32	8.66	6.90	7.73	5.29	6.64
0.05	6.13	6.49	5.67	5.76	5.01	4.60	3.48	4.36
0.10	4.01	4.63	4.09	4.24	3.27	2.40	2.17	2.61
Mean	6.69	6.41	5.78		5.28	4.27	3.90	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5% (50-70d)	C.D. at 5% (70-90d)
Seed treatment (S)	0.39	0.53
Fertiliser treatment (F)	0.29	0.38
S x F	0.69	0.92

for 0.10 X $N_{60+30}P_{30}$, 0.10 X $N_{90}P_{30}$ and unsoaked control X $N_{90}N_{30}$. At the later interval (70-90d) the minimum value was recorded in 0.10 X $N_{60+30}P_{30}$ which differed critically from the other interactions except 0.10 X $N_{90}P_{30}$ and water-soaked control X $N_{90}P_{30}$.

4.3.3 Leaf NPK content

Leaf NPK contents were significantly affected by the variants, but the effect differed from stage to stage. The data are summarised in Tables 27-29 and described briefly below:

4.3.3.1 Nitrogen

The effect of seed treatment, fertiliser treatment and their interaction significantly affected leaf nitrogen content at 50 and 70d, but at 90d, nitrogen content was significantly affected by seed treatment only (Table 27).

Seed treatment 0.025% gave significant maximum value at all the three stages. Nitrogen content was increased by 72.1, 43.6 and 56.1% over the control at 50, 70 and 90d respectively. Water-soaked control and unsoaked control,being at par, gave minimum value at 50d. At 70 and 90d, 0.10% gave minimum value which differed critically from other treatments, except water-soaked control and unsoaked control at 70d.

Fertiliser treatment $N_{60}P_{20}$ gave maximum value at 50 and 70d; but the effect was statistically equal to that for $N_{60+30}P_{30}$ at 50d, and $N_{90}P_{30}$ at 70d. Minimum value was noted in

Table 27: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on nitrogen content (%) in leaves of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{60}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	3.96	3.25	3.21	3.47	3.61	3.15	3.08	3.28	2.63	2.26	2.51	2.47
Water-soaked control	3.70	3.31	3.19	3.40	3.49	3.08	3.01	3.19	2.19	2.42	2.99	2.53
0.0125	5.05	4.25	5.66	4.99	4.16	4.01	4.04	4.07	3.19	3.03	3.15	3.12
0.025	5.65	5.98	5.92	5.85	4.65	4.92	4.16	4.58	3.92	4.50	3.44	3.95
0.05	4.91	5.45	4.56	4.97	3.96	3.76	3.99	3.90	3.31	3.62	3.03	3.32
0.10	4.68	4.00	4.37	4.35	3.13	3.01	3.08	3.07	2.18	2.05	1.78	2.00
Mean	4.66	4.37	4.49		3.83	3.66	3.56		2.90	2.98	2.82	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5% (50)	C.D. at 5% (70)	C.D. at 5% (90)
Seed treatment (S)	0.23	0.35	0.42
Fertiliser treatment (F)	0.17	0.21	N.S.
S x F	0.40	0.60	N.S.

N.S. Non-significant

$N_{90}P_{30}$ at 50d and $N_{60+30}P_{30}$ at 70d. However, the values were at par with those for $N_{60+30}P_{30}$ and $N_{90}P_{30}$ at 50 and 70d respectively.

Regarding interaction, 0.025 X $N_{90}P_{30}$ gave maximum value at 50 and 70d and differed critically from the other interactions, except 0.025 X $N_{60+30}P_{30}$, 0.0125 X $N_{60+30}P_{30}$ and 0.025 X $N_{60}P_{20}$ at 50d, and 0.025 X $N_{60}P_{20}$ at 70d. The minimum value was given by water-soaked control X $N_{60+30}P_{30}$ at 50 and 70d and differed significantly from those for most of the other interactions.

4.3.3.2 <u>Phosphorus</u>

Phosphorus content in the leaves was significantly affected by seed treatment, fertiliser treatment and their interaction at all stages of growth. However, at 50d, it was not significantly affected by fertiliser treatments (Table 28).

Seed treatment 0.025% gave significant maximum value at all the three stages of growth. The increase in phosphorus content due to 0.025% was 20.8, 31.6 and 44.4% in comparison with the control at 50, 70 and 90d respectively. The minimum value was given by 0.10% which differed critically from the other treatments, except unsoaked control at 50d.

Maximum value was given by $N_{60}P_{20}$ at 70 and 90d and the value was statistically equal to that of $N_{90}P_{30}$ at 70d and

Table 28: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on phosphorus content (%) in leaves of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	0.45	0.42	0.48	0.45	0.39	0.35	0.31	0.35	0.28	0.22	0.29	0.26
Water-soaked control	0.49	0.48	0.46	0.48	0.41	0.38	0.34	0.38	0.31	0.25	0.26	0.27
0.0125	0.52	0.54	0.51	0.52	0.48	0.46	0.43	0.46	0.38	0.31	0.36	0.35
0.025	0.59	0.60	0.55	0.58	0.51	0.52	0.48	0.50	0.39	0.41	0.39	0.39
0.05	0.46	0.49	0.42	0.46	0.37	0.33	0.32	0.34	0.26	0.28	0.32	0.29
0.10	0.39	0.41	0.40	0.40	0.31	0.29	0.27	0.29	0.21	0.20	0.22	0.21
Mean	0.48	0.49	0.47		0.41	0.39	0.36		0.31	0.28	0.31	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.05	0.03	0.02
Fertiliser treatment (F)	N.S.	0.02	0.02
S x F	0.08	0.05	0.04

N.S. Non-significant

$N_{60+30}P_{30}$ at 90d. Significant minimum value was noted in $N_{60+30}P_{30}$ and $N_{90}P_{30}$ at 70 and 90d respectively.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value at all the three stages but was at par with 0.025 X $N_{60}P_{20}$, 0.025 X $N_{60+30}P_{30}$, 0.0125 X $N_{90}P_{30}$ and 0.0125 X $N_{60}P_{20}$ at 50d. At 70d, its value was statistically equal to those for 0.025 X $N_{60}P_{20}$, 0.025 X $N_{60+30}P_{30}$ and 0.0125 X $N_{60}P_{20}$, and, at 90d with those for 0.025 X $N_{60}P_{20}$, 0.025 X $N_{60+30}P_{30}$ and 0.0125 X $N_{60}P_{20}$. At 50d, the minimum value was given by 0.10 X $N_{60}P_{20}$ which differed significantly from most of the other interactions. At 70d, 0.10 X $N_{60+30}P_{30}$ gave minimum value which was statistically equal to those for 0.10 X $N_{90}P_{30}$, 0.10 X $N_{60}P_{20}$, unsoaked control X $N_{60+30}P_{30}$ and 0.05 X $N_{60+30}P_{30}$. At 90d, minimum value was recorded in 0.10 X $N_{90}P_{30}$ which was at par with those for 0.10 X $N_{60}P_{20}$, 0.10 X $N_{60+30}P_{30}$ and unsoaked control X $N_{90}P_{30}$.

4.3.3.3 Potassium

The effect of seed treatment, fertiliser treatment and their interaction was significant only at 50d. At 70d, the effect of soaking treatment only was found significant (Table 29).

Seed treatment 0.025% gave significant maximum value increasing potassium content by 28.7 and 36.3% over the control at 50 and 70d respectively. Water-soaked and unsoaked controls,

Table 29: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on potassium content (%) in leaves of mustard variety Varuna.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	4.75	4.63	4.52	4.63	4.08	4.05	4.00	4.04	3.90	3.88	3.76	3.85
Water-soaked control	4.68	4.72	4.48	4.63	4.12	4.09	4.10	4.10	3.87	3.79	3.83	3.83
0.0125	5.89	5.86	5.75	5.83	5.32	5.28	5.25	5.28	4.01	3.96	3.92	3.96
0.025	5.96	5.99	5.93	5.96	5.55	5.63	5.59	5.59	4.09	4.16	3.10	3.78
0.05	5.20	4.24	5.31	4.92	4.20	4.18	4.30	4.23	3.72	3.76	2.72	3.40
0.10	5.18	4.11	5.25	4.85	4.10	3.89	4.21	4.07	2.70	2.68	2.61	2.66
Mean	5.28	4.93	5.21		4.56	4.52	4.58		3.72	3.71	3.32	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.09	0.29	N.S.
Fertiliser treatment (F)	0.07	N.S.	N.S.
S x F	0.15	N.S.	N.S.

N.S. Non-significant

being at par, gave minimum value at 50d. At 70d, unsoaked control gave minimum value which differed critically from the rest of the treatments.

$N_{60}P_{20}$ gave maximum value which was at par with that of $N_{60+30}P_{30}$. Significant minimum value was given by $N_{90}P_{30}$.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value which was statistically equal to those for 0.025 X $N_{60}P_{20}$, 0.025 X $N_{60+30}P_{30}$, 0.0125 X $N_{60}P_{20}$ and 0.0125 X $N_{90}P_{30}$. Minimum value was given by 0.10 X $N_{90}P_{30}$ which differed critically from other interactions, except 0.05 X $N_{90}P_{30}$.

4.3.4 Yield characteristics

Seed treatment, fertiliser treatment and their interaction significantly affected pods/plant, seeds/pod, hecto-litre weight, oil content and yields of seed and oil. The data are summarised in Tables 30-31 and are described briefly below:

4.3.4.1 Pods/plant

Seed treatment 0.025% gave significant maximum value for number of pods, giving 36.5% more pods in comparison with control. Minimum value was given by 0.10% which was statistically equal to that of unsoaked control.

Fertiliser treatment $N_{60}P_{20}$ gave significant maximum number of pods. The minimum value was given by $N_{60+30}P_{30}$ which was statistically equal to that of $N_{90}P_{30}$.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value which differed critically from the other interactions, except 0.025 X $N_{60}P_{20}$ and 0.0125 X $N_{60}P_{20}$. Minimum value was given by unsoaked control X $N_{90}P_{30}$ which was statistically equal to 0.10 X $N_{60+30}P_{30}$, water-soaked control X $N_{90}P_{30}$ and 0.10 X $N_{90}P_{30}$ (Table 30).

4.3.4.2 Seeds/pods

Seed treatment 0.025% gave significant maximum value and the increase in number of seeds over the control was 12.0%. Minimum value was noted for 0.10% which was at par with those for unsoaked control, water-soaked control and 0.05%.

Significant maximum and minimum values were given by $N_{60}P_{20}$ and $N_{60+30}P_{30}$ respectively.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value which was statistically equal to that of 0.0125 X $N_{60}P_{20}$. Minimum value was given by 0.10 X $N_{60+30}P_{30}$ which differed critically from most of the interactions (Table 30).

4.3.4.3 Hecto-litre weight

Significant maximum value was given by 0.0125% which increased the hecto-litre weight by 4.3% over control. Minimum value was noted with 0.10% which differed critically from other treatments.

Table 30: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on pods/plants, seeds/pod and hecto-litre weight (kg) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Pods/plant				Seeds/pod				Hectro-litre weight			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	182.04	155.28	170.29	169.20	12.51	11.53	10.18	11.41	63.00	65.17	63.60	63.92
Water-soaked control	184.96	159.15	173.14	172.42	12.69	11.58	10.58	11.62	63.17	65.43	63.33	63.98
0.0125	251.55	185.66	190.89	209.37	13.42	13.01	11.03	12.49	66.25	66.33	67.58	66.72
0.025	251.85	254.78	199.51	235.38	13.18	14.24	11.65	13.02	65.18	65.25	66.12	65.52
0.05	211.11	172.18	180.11	187.80	12.79	11.69	10.97	11.82	64.45	64.25	65.42	64.71
0.10	177.65	163.23	155.79	165.56	12.44	11.31	10.16	11.30	63.44	63.44	64.00	63.63
Mean	209.86	181.71	178.29		12.84	12.23	10.76		64.25	64.98	65.00	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	4.93	0.52	0.23
Fertiliser treatment (F)	3.48	0.37	0.16
S x F	8.53	0.91	0.39

Fertiliser treatment $N_{60+30}P_{30}$ gave maximum value which was at par with that of $N_{90}P_{30}$. Significant lowest value was given by $N_{60}P_{20}$.

Regarding interaction, significant maximum value was recorded in 0.0125 X $N_{60+30}P_{30}$. Minimum value was given by unsoaked control X $N_{60}P_{20}$ which was at par with those for water-soaked control X $N_{60}P_{20}$ and water-soaked control X $N_{60+30}P_{30}$ (Table 30).

4.3.4.4 <u>Seed yield</u>

Seed treatment 0.025% gave significant maximum value, increasing the yield by 14.9% over the control. Minimum value was given by 0.10% which was statistically equal to those for unsoaked and water-soaked controls.

Significant maximum and minimum value was given by fertiliser treatments $N_{60}P_{20}$ and $N_{60+30}P_{30}$ respectively.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value which was statistically equal to those for 0.0125 X $N_{60}P_{20}$ and 0.025 X $N_{60}P_{20}$. Minimum value was given by water-soaked control X $N_{90}P_{30}$ which differed critically from other interactions, except 0.10 X $N_{60}P_{20}$, unsoaked control X $N_{90}P_{30}$ and 0.10 X $N_{60+30}P_{30}$ (Table 31).

4.3.4.5 <u>Oil content</u>

Seed treatment 0.025% gave significant maximum value for oil content. The increase in oil content due to this

Table 31: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on seed yield (kg/ha), oil content (%) and oil yield (kg/ha) of mustard variety Varuna.

Seed treatments (% pyridoxine)	Seed yield				Oil content				Oil yield			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	1015.64	976.81	993.49	995.31	29.65	28.45	28.50	28.87	310.09	277.75	283.09	290.31
Water-soaked control	1036.48	954.01	1018.24	1002.91	29.35	28.05	28.85	28.75	304.34	273.73	293.88	290.65
0.0125	1185.03	1119.77	1064.14	1122.98	33.00	30.00	30.60	31.20	391.02	335.97	325.59	350.86
0.025	1176.19	1190.69	1090.80	1152.56	34.00	34.50	33.30	33.93	399.86	398.51	363.63	387.33
0.05	1042.70	1085.01	1047.78	1058.49	32.45	32.95	31.55	32.32	338.41	357.55	330.65	342.20
0.10	973.04	1015.01	980.55	989.53	30.80	31.30	30.00	30.70	299.77	329.25	294.40	307.81
Mean	1071.51	1056.88	1032.50		31.54	30.88	30.47		340.58	328.79	315.21	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	Seed yield C.D. at 5%	Oil content C.D. at 5%	Oil yield C.D. at 5%
Seed treatment (S)	17.65	0.64	14.22
Fertiliser treatment (F)	12.74	0.46	10.26
S X F	30.56	1.10	24.63

treatment was 18.0% over the control. Water-soaked control and unsoaked control, being at par, gave minimum value.

Significant maximum value was given by $N_{60}P_{20}$. Minimum value was given by $N_{60+30}P_{30}$ which was at par with that of $N_{90}P_{30}$.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$ gave maximum value and differed critically from the other interactions, except 0.025 X $N_{60}P_{20}$. Minimum value was given by water-soaked control X $N_{90}P_{30}$ which was at par with those for unsoaked control X $N_{90}P_{30}$, unsoaked control X $N_{60+30}P_{30}$ and water-soaked control X $N_{60+30}P_{30}$ (Table 31).

4.3.4.6 <u>Oil yield</u>

Significant maximum oil yield was given by 0.025% which increased the oil yield by 33.3% over the control. Unsoaked and water-soaked controls, being at par, gave minimum value.

Significant maximum and minimum values were given by $N_{60}P_{20}$ and $N_{60+30}P_{30}$ respectively.

Regarding interaction effect, 0.025 X $N_{60}P_{20}$ gave maximum value which was statistically equal to those for 0.025 X $N_{90}P_{30}$ and 0.0125 X $N_{60}P_{20}$. Minimum value was noted with water-soaked control X $N_{90}P_{30}$ which differed from most of the interactions (Table 31).

4.3.5 <u>Quality characteristics</u>

Acid, iodine and saponification value were studied to assess the quality of oil. Only saponification value was significantly affected by seed treatment, fertiliser treatment and their interaction. Therefore, the data regarding this parameter are described below (Table 32).

4.3.5.1 Saponification value

Maximum value was noted with 0.0125% which differed critically from other treatments, except 0.025%. There was 15.5% increase in comparison with the control. Unsoaked and water-soaked controls, being at par, gave minimum values.

Significant maximum value was given by $N_{60}P_{20}$. Minimum value was given by $N_{90}P_{30}$ which was statistically equal to that of $N_{60+30}P_{30}$.

Regarding interaction effect, 0.0125 X $N_{60}P_{20}$ gave maximum value which was at par with those for 0.025 X $N_{60}P_{20}$, 0.0125 X $N_{60+30}P_{30}$, 0.025 X $N_{60+30}P_{30}$, 0.025 X $N_{90}P_{30}$ and 0.0125 X $N_{90}P_{30}$. Minimum value was recorded in unsoaked control X $N_{90}P_{30}$ which differed critically from most of the interactions.

4.4 Experiment 4

In this factorial randomised field trial, the effect of pre-sowing seed treatment with pyridoxine, varietal differences and of their interaction (S X V) was studied on growth, net assimilation rate, leaf NPK content, oil content of seed, seed and oil yield and quality characteristics of oil. Since unsoaked and water-soaked controls were found to be at par for

Table 32: Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on acid value, iodine value and saponification value of mustard variety Varuna.

Seed treatments (% pyridoxine)	Acid value				Iodine value				Saponification value			
	Fertiliser treatments											
	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean	$N_{60}P_{20}$	$N_{90}P_{30}$	$N_{60+30}P_{30}$	Mean
Unsoaked control	4.62	4.62	4.62	4.62	98.03	102.29	90.48	96.93	156.80	146.70	149.50	151.00
Water-soaked control	4.80	4.62	4.51	4.64	99.14	101.29	90.98	97.14	158.00	149.30	151.60	152.97
0.0125	3.96	3.16	4.02	3.71	102.18	105.48	101.35	103.00	180.00	172.03	177.90	176.64
0.025	3.30	3.82	3.96	3.69	107.84	107.24	104.95	106.67	178.20	173.50	175.50	175.73
0.05	2.90	3.30	3.52	3.24	100.18	106.33	94.20	100.24	168.30	168.30	168.60	168.40
0.10	2.10	3.16	3.22	2.83	95.03	95.33	88.30	92.89	164.90	160.70	160.10	161.90
Mean	3.61	3.78	3.98		100.40	102.99	95.04		167.70	161.76	163.87	

N.B. A basal dose of 30 kg K/ha was applied uniformly at sowing.

	Acid value C.D. at 5%	Iodine value C.D. at 5%	Saponification value C.D. at 5%
Seed treatment (S)	N.S.	N.S.	5.00
Fertiliser treatment (F)	N.S.	N.S.	3.54
S x F	N.S.	N.S.	8.67

N.S. Non-significant

all parameters in this experiment also, the increase due to treatment was compared with water-soaked control. The data are described below and are summarised in Tables 33-44.

4.4.1 Growth characteristics

The effect of seed treatment, varietal response and their interaction was significant on all parameters studied at all three stages of growth, except varietal response for fresh weight at 70d. The data are summarised in Tables 33-37 and are described briefly below:

4.4.1.1 Shoot length/plant

Seed treatment 0.0125% gave significant maximum value at all the three growth stages, except at 90d where its effect was at par with that of 0.025%. The increase in shoot length due to 0.0125% treatment was 13.6, 25.1 and 13.3% over control at 50, 70 and 90d respectively. Significant minimum value was given by 0.10% at 50 and 90d; but at 70d the value was statistically equal to that of unsoaked control.

Maximum value was noted with Varuna which was at par with that of RK-8203 at 50d. At 70 and 90d significant maximum value was given by RK-8203. Significant lowest value was given by PR-18 at all the stages of growth.

Regarding interaction effect, 0.0125 X Varuna gave maximum value at 50d which differed critically from other interactions, except 0.05 X RK-8203. At 70d, maximum value was recorded in 0.05 X RK-8203 which was at par with that of 0.0125 X Varuna. At 90d, 0.025 X RK-8203 gave maximum value which was statistically equal to that for 0.0125 X Varuna. Minimum value was given by 0.10 X PR-18 at 50 and 90d which was statistically equal to that for 0.05 X PR-18 at 50d and 0.10 X Varuna at 90d. At 70d, minimum value was given by water-soaked control X Varuna which differed critically from other interactions, except unsoaked control X Varuna, 0.10 X PR-18 and 0.05 X PR-18 (Table 33).

4.4.1.2 Root length/plant

Seed treatment 0.0125% gave maximum value at 50 and 70d; but it was statistically equal to that of 0.025%. At 90d, maximum value was recorded in 0.025% which was at par with that of 0.0125%. The increase in root length due to treatment giving maximum value at respective stages was 3.6, 8.6 and 13.2% over control. Significant minimum value was given by 0.10% at all the stages.

Significant maximum value was noted with RK-8203 at 50d, while, at 70 and 90d, the maximum value was given by Varuna which was statistically equal to that of RK-8203. Significant lowest value was given by PR-18 at all the stages.

Regarding interaction effect, at 50d, 0.05 X RK-8203 gave maximum value which was statistically equal to those for 0.0125 X Varuna and 0.025 X RK-8203. At 70d, maximum value was

Table 33: Effect of pre-sowing seed treatment with pyridoxine on shoot length/plant (cm) of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	43.49	61.65	59.79	54.98	82.58	102.29	72.19	85.69	138.69	138.0C	129.74	135.48
Water-soaked control	46.44	58.39	55.54	53.46	88.46	110.37	70.12	89.65	141.83	139.61	130.33	137.26
0.0125	55.93	48.58	77.61	60.71	100.44	96.61	139.56	112.20	162.09	133.93	170.33	155.45
0.025	61.88	32.45	60.62	51.65	115.35	81.50	121.67	106.17	176.00	127.50	153.60	152.37
0.05	72.61	28.17	55.58	52.12	140.12	75.11	93.75	102.99	167.81	118.33	121.62	135.92
0.10	59.44	22.55	42.37	41.45	90.19	72.35	91.65	84.73	130.95	106.50	108.03	115.16
Mean	56.63	41.97	58.59		102.86	89.71	98.16		152.89	127.21	135.61	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	4.86	4.69	3.94
Variety (V)	3.51	3.38	2.84
S x V	8.42	8.12	6.82

given by 0.0125 X Varuna which differed critically from the other interactions, except 0.05 X RK-8203, 0.025 X RK-8203 and 0.025 X Varuna. At 90d, 0.025 X Varuna gave maximum value which was at par with those for 0.0125 X Varuna, 0.05 X RK-8203, 0.025 X RK-8203 and 0.05 X Varuna. Minimum value was given by 0.10 X PR-18 which differed critically from most of the interactions at all the three stages (Table 34).

4.4.1.3 Leaf number/plant

Seed treatment 0.0125% gave significant maximum value at all the three stages, except at 50d when it was at par with that of 0.025%. The increase in number of leaves due to 0.0125% was 10.7, 15.9 and 3.7% over control at 50, 70 and 90d respectively. Significant lowest value was given by 0.10% at 50 and 90d; but, at 70d, minimum value was given by water-soaked control which was at par with those for unsoaked control and 0.10%.

Variety Varuna produced significant maximum number of leaves at 50d, while at 70 and 90d, significant maximum number was recorded for RK-8203. Minimum value was given by PR-18 at 50 and 90d which was statistically equal to that of RK-8203 at 50d, and Varuna at 90d. At 70d, PR-18 gave significant lowest value.

Regarding interaction effect, at 50d, 0.0125 X Varuna gave maximum value which differed critically from all other interactions, except 0.05 X RK-8203. At 70 and 90d, significant

Table 34: Effect of pre-sowing seed treatment with pyridoxine on root length/plant (cm) of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	12.60	12.22	12.03	12.28	13.68	13.11	13.70	13.16	14.29	14.25	14.83	14.46
Water-soaked control	12.93	12.34	12.39	12.55	13.77	13.77	14.08	13.54	14.58	14.09	14.43	14.37
0.0125	13.00	11.44	14.56	13.00	15.00	12.56	16.54	14.70	16.03	13.79	17.51	15.78
0.025	14.44	10.19	13.70	12.77	16.21	11.79	15.55	14.52	17.17	13.76	17.89	16.27
0.05	15.01	9.25	11.95	12.07	16.41	10.32	14.49	13.74	17.22	11.95	16.93	15.37
0.10	10.53	9.03	11.46	10.34	11.99	9.52	12.78	11.43	12.25	11.63	12.83	12.24
Mean	13.09	10.75	12.68		14.51	11.85	14.52		15.26	13.25	15.74	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.38	0.69	0.72
Variety (V)	0.28	0.49	0.52
S x V	0.65	1.19	1.25

maximum value was given by 0.05 X RK-8203. On the other hand, significant minimum value was given by 0.10 X Varuna at 50d. At 70 and 90d, 0.10 X PR-18 gave minimum value which differed critically from all other, except 0.10 X Varuna at 90d (Table 35).

4.4.1.4 <u>Fresh weight/plant</u>

0.0125% pyridoxine gave maximum value at all the stages and differed critically from all other treatments, except 0.025% at 50d. The increase in fresh weight was 34.5, 14.0 and 24.5% over control at 50, 70 and 90d respectively. Significant minimum value was given by 0.10% at all the three stages.

Varuna performed best at 50 and 90d and gave significant maximum value. At these stages significant lowest value was given by RK-8203 at 50d, PR-18 at 90d. As mentioned earlier on p.112, the varietal differences at 70d were non-significant.

Regarding interaction effect, 0.0125 X Varuna gave significant maximum value at 50 and 90d. At 70d, maximum value was given by 0.05 X RK-8203 which differed critically from the other interactions, except 0.0125 X Varuna. Minimum value at 50d was given by 0.10 X RK-8203 and, at 70 and 90d, by 0.10 X PR-18. These values differed critically from most of the interactions at the respective stages (Table 36).

Table 35: Effect of pre-sowing seed treatment with pyridoxine on leaf number/plant of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	5.36	7.06	7.67	6.69	16.33	17.00	13.83	15.72	22.83	22.36	19.21	21.47
Water-soaked control	5.30	7.02	7.30	6.54	16.67	16.60	13.33	15.53	21.67	22.93	20.69	21.76
0.0125	6.37	6.67	8.67	7.24	18.33	15.67	20.00	18.00	24.25	21.18	25.26	23.56
0.025	7.12	6.00	7.80	6.97	20.30	15.33	17.00	17.54	26.73	19.23	20.00	21.99
0.05	8.67	5.67	5.67	6.67	23.67	13.00	15.67	17.45	29.02	17.11	18.68	21.60
0.10	6.33	5.00	4.00	5.11	22.00	10.67	14.33	15.67	22.81	14.05	14.29	17.05
Mean	6.53	6.24	6.85		19.55	14.71	15.69		24.55	19.48	19.69	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.43	0.39	1.07
Variety (V)	0.31	0.28	0.78
S x V	0.74	0.67	1.86

Table 36: Effect of pre-sowing seed treatment with pyridoxine on fresh weight/plant (g) of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	20.19	40.35	32.51	31.02	39.44	54.55	49.26	47.75	70.59	80.66	89.02	80.09
Water-soaked control	17.69	39.41	30.69	29.26	37.61	56.12	47.24	46.99	67.98	85.28	92.78	82.01
0.0125	30.45	38.13	49.66	39.41	47.54	50.59	62.66	53.59	100.78	75.51	129.97	102.09
0.025	35.38	35.64	41.96	37.66	51.60	42.57	51.22	48.46	81.72	62.92	101.11	81.92
0.05	42.01	26.50	36.63	35.05	64.06	38.97	37.28	46.77	76.87	55.41	98.78	77.02
0.10	16.42	20.17	29.05	21.88	34.43	31.84	31.37	32.55	60.05	45.90	73.82	59.92
Mean	27.02	33.37	36.75		45.78	45.77	46.51		76.33	67.61	97.58	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	2.95	3.56	5.85
Variety (V)	2.13	N.S.	4.22
S x V	5.11	6.16	10.13

N.S. Non-significant

4.4.1.5 Dry weight/plant

Seed treatment 0.0125% gave maximum value at 50 and 70d and differed critically from others, except 0.025% at 50d. At 90d, 0.025% proved best but the value was at par with that of 0.0125%. The increase in dry matter due to the treatment (0.0125 or 0.025%), giving maximum value at the respective stages,was 19.8, 10.6 and 12.8% over control. Significant lowest value was given by 0.10% at all the stages.

Variety Varuna gave significant maximum value at 50 and 70d, but at 90d maximum value was given by RK-8203 which was statistically equal to that of Varuna. Significant lowest value was given by RK-8203 at 50d and by PR-18 at 70 and 90d.

Among interaction effect, 0.05 X RK-8203 gave maximum value at 50d, and was statistically equal to those for water-soaked control X PR-18 and 0.0125 X Varuna. Minimum value was given by unsoaked control X RK-8203 which was at par with those for 0.10 X PR-18 and water-soaked control X RK-8203. At 70d, maximum value was recorded in 0.0125 X Varuna which differed critically from other interactions, except 0.0125 X Varuna. At 90d, significant maximum value was given by 0.05 X RK-8203. Minimum value at 70 and 90d was given by 0.10 X PR-18 which differed critically from other interactions, except 0.05 X PR-18 at 90d (Table 37).

Table 37: Effect of pre-sowing seed treatment with pyridoxine on dry weight/plant (g) of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	2.17	6.00	4.78	4.32	6.45	9.39	8.44	8.09	9.94	12.06	12.72	11.57
Water-soaked control	2.49	6.44	4.43	4.45	6.65	9.73	8.23	8.20	10.99	13.04	11.56	11.86
0.0125	4.37	5.33	6.29	5.33	7.98	7.78	11.45	9.07	11.50	9.53	16.95	12.66
0.025	5.42	4.16	6.14	5.24	8.47	5.80	10.74	8.34	16.66	8.21	15.26	13.38
0.05	6.70	3.79	4.55	5.01	9.52	4.80	7.11	7.14	19.64	6.09	10.18	11.97
0.10	3.43	2.34	3.28	3.02	7.53	3.46	5.85	5.61	10.50	5.79	9.74	8.68
Mean	4.09	4.68	4.91		7.77	6.83	8.64		13.21	9.12	12.74	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.30	0.51	1.15
Variety (V)	0.22	0.37	0.83
S x V	0.52	0.88	1.99

4.4.2 Net assimilation rate (NAR)

The effect of seed treatment, varietal response and their interaction was significant at both the intervals, viz., 50-70d and 70-90d (Table 38).

Treatment 0.0125% gave maximum value and differed critically from other treatments, except 0.025% at both intervals. The increase in NAR due to 0.0125% was 34.5 and 42.0% over control at 50-70d and 70-90d respectively. Minimum value was given by 0.10% and was at par with those for unsoaked and water-soaked controls at each interval.

Varuna performed best and gave maximum value at first interval (50-70d). However, its performance was at par with that of RK-8203; while at 70-90d, maximum value was given by RK-8203 which was at par with that of Varuna. PR-18 gave significant minimum value at both intervals.

Regarding interaction effect, 0.0125 X Varuna gave significant maximum value at both the intervals. However, at 70-90d, it was at par with 0.05 X RK-8203. Minimum value was recorded for 0.10 X PR-18 which differed critically from most of the interactions at each interval.

4.4.3 Leaf NPK content

The effect of seed treatment, varietal response and their interaction was found significant on nitrogen and phosphorus content in leaves at all stages. However, potassium was

Table 38: Effect of pre-sowing seed treatment with pyridoxine on net assimilation rate ($\times 10^{-3}$ g/cm^2/d) of three varieties of mustard.

Seed treatments (% pyridoxine)	Days interval							
	50-70d				70-90d			
	Varieties							
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	5.45	4.63	5.88	5.32	3.92	3.39	4.20	3.84
Water-soaked control	5.16	4.68	5.87	5.24	3.68	3.33	4.27	3.76
0.0125	6.94	4.32	9.88	7.05	5.54	2.52	7.98	5.34
0.025	7.72	3.35	8.19	6.42	6.01	2.34	5.33	4.56
0.05	8.57	2.30	7.19	6.02	6.69	1.41	4.05	4.05
0.10	6.87	2.24	5.15	4.75	5.04	1.23	3.09	3.12
Mean	6.79	3.59	7.03		5.15	2.37	4.82	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.72	0.80
Variety (V)	0.52	0.58
S x V	1.25	1.39

significantly affected by soaking treatment at 50 and 70d. Varietal response was also significant at these two stages, while interaction effect was significant only at 50d. The data are summarised in Tables 39-41 and are described briefly below:

4.4.3.1 Nitrogen

Seed treatment 0.025% gave maximum nitrogen content at 50 and 90d and differed critically from other treatments, except 0.0125% at 90d. At 70d, 0.0125% gave maximum value which was at par with that of 0.025%. The increase in nitrogen content due to the treatment giving maximum value at respective stages was 10.0, 4.6 and 19.6% over control. Significant lowest value was given by 0.10% at all the three stages.

Significant maximum and minimum value was obtained with Varuna and PR-18 respectively at all the stages.

Regarding interaction effect, at 50d, 0.05 X RK-8203 gave maximum value and was statistically equal to that of 0.025 X Varuna. At 70 and 90d, 0.0125 X Varuna gave maximum value and differed critically from all other interactions, except 0.025 X Varuna at 90d. Significant lowest value was given by 0.10 X PR-18 at all the stages (Table 39).

4.4.3.2 Phosphorus

Seed treatment 0.0125% gave maximum value at 50 and 70d and differed critically from other treatments, except 0.025%.

Table 39: Effect of pre-sowing seed treatment with pyridoxine on nitrogen content (%) in leaves of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	3.02	4.90	4.88	4.27	3.31	4.51	4.09	3.97	2.37	3.25	3.89	3.17
Water-soaked control	3.44	4.70	4.72	4.29	3.53	4.23	4.59	4.12	2.25	3.69	3.39	3.11
0.0125	4.28	3.78	5.61	4.56	4.01	3.53	5.39	4.31	3.19	2.89	4.95	3.68
0.025	4.91	3.57	5.67	4.72	4.65	3.01	5.15	4.27	3.68	2.69	4.80	3.72
0.05	5.69	3.06	4.82	4.52	5.25	2.96	4.47	4.23	4.17	2.31	3.57	3.35
0.10	3.91	2.69	4.56	3.72	3.05	2.33	4.12	3.17	2.44	2.01	3.31	2.59
Mean	4.21	3.78	5.01		3.97	3.43	4.64		3.02	2.81	3.99	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.04	0.06	0.10
Variety (V)	0.03	0.04	0.08
S x V	0.06	0.10	0.18

At 90d, maximum value was recorded in 0.025% which was at par with those given by 0.0125 and 0.05%. The increase in phosphorus content due to treatment giving maximum value at the respective stages was 12.5, 9.1 and 18.8% over control. Significant lowest value was recorded in treatment 0.10% at all the stages.

Varuna and PR-18 gave significant maximum and minimum value respectively at all the stages.

Regarding interaction effect, 0.025 X Varuna gave maximum value at all the stages and differed critically from other interactions, except 0.0125 X Varuna, 0.05 X Varuna and 0.05 X RK-8203 at 50d; 0.0125 X Varuna at 70d, and 0.0125 X Varuna and 0.05 X RK-8203 at 90d. Minimum value was given by 0.10 X PR-18 at all the stages which differed critically from most of the interactions (Table 40).

4.4.3.3 Potassium

The treatment 0.0125% gave significant maximum value for potassium content at both 50 and 70d stages, except at 70d where it was statistically equal to 0.025%. The increase in potassium content due to 0.0125% was 9.8 and 12.8% over the control at 50 and 70d respectively. Significant minimum value was given by 0.10% at both stages.

Varuna gave significant maximum value at 50d; while at 70d; maximum value was given by RK-8203 which was at par

Table 40: Effect of pre-sowing seed treatment with pyridoxine on phosphorus content (%) in leaves of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	0.41	0.52	0.53	0.49	0.35	0.45	0.46	0.42	0.28	0.36	0.34	0.33
Water-soaked control	0.40	0.51	0.54	0.48	0.38	0.47	0.48	0.44	0.26	0.33	0.37	0.32
0.0125	0.53	0.49	0.61	0.54	0.49	0.38	0.56	0.48	0.37	0.26	0.49	0.37
0.025	0.55	0.41	0.64	0.53	0.51	0.31	0.59	0.47	0.41	0.21	0.51	0.38
0.05	0.59	0.32	0.59	0.50	0.54	0.29	0.41	0.41	0.49	0.20	0.38	0.36
0.10	0.43	0.31	0.43	0.39	0.41	0.23	0.32	0.32	0.31	0.19	0.28	0.26
Mean	0.49	0.43	0.56		0.45	0.36	0.47		0.35	0.26	0.39	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.03	0.02	0.02
Variety (V)	0.02	0.01	0.02
S x V	0.05	0.03	0.04

with that of Varuna. Significant lowest value was given by PR-18 at both the stages.

Regarding interaction effect, 0.0125 X Varuna gave maximum value and differed critically from all other interactions. Minimum value was given by 0.10 X PR-18 which was at par with that of 0.05 X PR-18 (Table 41).

4.4.4 Yield characteristics

Yield was determined in terms of pods/plant, seeds/pod, hecto-litre weight, oil content, seed and oil yield. The effect of seed treatment, varietal response and their interaction was found significant for these parameters. The data are summarised in Tables 42-43 and are described briefly below:

4.4.4.1 Pods/plant

Seed treatment 0.0125% resulted in significant maximum number of pods. The pod number was increased by 10.8% over control due to this treatment. The minimum value was recorded in 0.10% which differed critically from all other treatments.

Significant maximum and minimum value was given by Varuna and PR-18 respectively.

Regarding interaction effect, 0.0125 X Varuna and 0.10 X Varuna gave significant maximum and minimum values respectively (Table 42).

Table 41: Effect of pre-sowing seed treatment with pyridoxine on potassium content (%) in leaves of three varieties of mustard.

Seed treatments (% pyridoxine)	Sampling days after sowing											
	50				70				90			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	4.55	4.26	4.51	4.44	3.52	3.66	3.11	3.43	3.06	2.89	2.67	2.87
Water-soaked control	4.32	4.25	4.58	4.39	3.65	3.58	3.05	3.43	3.11	2.72	2.86	2.89
0.0125	4.72	3.83	5.91	4.82	4.16	3.19	4.26	3.87	3.81	2.46	3.91	3.39
0.025	4.83	3.78	4.98	4.53	4.23	3.06	3.99	3.76	3.89	2.15	3.08	3.04
0.05	5.01	3.61	4.32	4.32	3.79	3.01	3.85	3.55	3.67	2.11	2.98	2.92
0.10	4.11	3.48	4.14	3.91	3.25	2.98	3.18	3.14	2.88	2.01	2.62	2.50
Mean	4.59	3.87	4.74		3.77	3.25	3.57		3.40	2.39	3.02	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	0.15	0.28	N.S.
Variety (V)	0.11	0.20	N.S.
S x V	0.26	N.S.	N.S.

N.S. Non-significant

Table 42: Effect of pre-sowing seed treatment with pyridoxine on pods/plant, seeds/pod and hecto-litre weight (kg) of three varieties of mustard.

Seed treatments (% pyridoxine)	Pods/plant				Seeds/pod				Hecto-litre weight			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	156.36	167.40	168.75	164.17	11.67	12.65	10.86	11.73	64.00	65.00	64.00	64.33
Water-soaked control	158.65	169.67	166.53	164.95	11.49	12.81	11.06	11.79	64.50	65.00	64.75	64.75
0.0125	172.05	163.21	213.23	182.83	13.41	12.34	14.93	13.56	66.50	64.00	66.95	65.82
0.025	182.21	155.60	190.64	176.15	13.79	11.03	14.14	12.99	67.75	63.50	66.05	65.77
0.05	196.15	146.25	179.77	174.06	14.37	10.33	13.37	12.69	67.50	62.25	64.50	64.75
0.10	146.36	135.78	120.19	134.11	12.31	10.04	12.27	11.54	65.00	60.50	62.25	62.58
Mean	168.63	156.32	174.02		12.84	11.53	12.77		65.54	63.38	64.54	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	1.86	0.38	0.57
Variety (V)	1.34	0.27	0.41
S x V	3.22	0.65	0.98

4.4.4.2 Seeds/pod

Seed treatment 0.0125%, giving significant maximum value, increased the seed number by 15.0% over control. Minimum value was given by 0.10% which was statistically equal to that of unsoaked and water-soaked controls.

RK-8203 gave maximum value and was at par with that of Varuna. PR-18 gave significant lowest value.

Regarding interaction effect, 0.0125 X Varuna gave maximum value and differed critically from other interactions, except 0.05 X RK-8203. Minimum value was given by 0.10 X PR-18 which was at par with that of 0.05 X PR-18 (Table 42).

4.4.4.3 Hecto-litre weight

Seed treatment 0.0125% gave maximum value but was statistically equal to that of 0.025%. The treatment 0.0125% increased the hecto-litre weight by 1.7% in comparison with control. Significant lowest value was given by 0.10%.

RK-8203 and PR-18 gave significant maximum and minimum value respectively.

Regarding interaction 0.025 X RK-8203 gave maximum value which was statistically equal to those for 0.05 X RK-8203 and 0.0125 X Varuna. Significant lowest value was given by 0.10 X PR-18 (Table 42).

4.4.4.4 Seed yield

Seed treatment 0.025% gave maximum value which was at par with that for 0.0125%. The increase in yield due to 0.025% was 3.8% in comparison with control. Significant lowest value was recorded with 0.10%.

Significant maximum and minimum value was noted with Varuna and PR-18 respectively.

Regarding interaction effect, maximum value was given by 0.05 X RK-8203 which differed critically from other interactions, except 0.0125 X Varuna. Minimum value was given by 0.10 X PR-18 which was at par with that of 0.10 X RK-8203 (Table 43).

4.4.4.5 Oil content

Maximum value for oil content was noted with 0.0125% which was statistically equal to that of 0.025%. The increase in oil content due to 0.0125% was 4.4% over control. Significant lowest value was given by 0.10%.

RK-8203 gave maximum value which was at par with that of Varuna. Significant lowest value was given by PR-18.

Regarding interaction 0.0125 X Varuna gave maximum value which was statistically equal to those for 0.0125 X RK-8203, 0.025 X RK-8203 and 0.025 X Varuna. Minimum value was given by 0.10 X PR-18 which was at par with that of 0.05 X PR-18 (Table 43).

Table 43: Effect of pre-sowing seed treatment with pyridoxine on seed yield (kg/ha), oil content (%) and oil yield (kg/ha) of three varieties of mustard.

Seed treatments (% pyridoxine)	Seed yield				Oil content				Oil yield			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	1012.11	1069.00	1106.78	1062.63	32.40	32.00	32.10	32.17	327.89	342.14	355.33	341.79
Water-soaked control	1028.67	1082.30	1098.17	1069.71	32.35	31.50	32.90	32.25	332.74	340.98	361.36	345.03
0.0125	1078.60	1056.70	1176.33	1103.88	34.95	30.40	35.70	33.68	377.03	321.29	419.89	372.74
0.025	1080.47	1112.37	1136.63	1109.82	34.65	30.25	34.40	33.10	374.43	306.29	379.69	353.47
0.05	1199.70	945.83	1006.27	1050.60	32.80	28.95	32.95	31.57	393.44	273.77	331.52	332.91
0.10	930.83	911.70	994.00	945.51	32.25	28.05	30.75	30.35	300.13	255.67	305.60	287.13
Mean	1055.06	1029.65	1086.36		33.23	30.19	33.13		350.94	306.69	358.89	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	14.64	0.93	10.51
Variety (V)	10.57	0.67	7.43
S x V	25.36	1.61	18.19

4.4.4.6 Oil yield

Maximum oil yield was recorded in 0.0125% treatment which differed critically from other treatments. The increase in oil yield due to 0.0125% was 8.0% in comparison with control. Significant lowest value was given by 0.10%.

The values recorded in varietal response critically differed from each other. Maximum and minimum value was given by Varuna and PR-18 respectively.

Regarding interaction effect, maximum value was noted with 0.0125 X Varuna which differed critically from other interactions. Minimum value was given by 0.10 X PR-18 which was at par with that of 0.05 X PR-18 (Table 43).

4.4.5 Quality characteristics

Among the three parameters selected to assess the quality of oil, iodine and saponification values were found to be affected significantly. The data regarding these two parameters are summarised in Table 44 and are described briefly below:

4.4.5.1 Iodine value

The effect of seed treatment and varietal response was significant while interaction effect was non-significant.

Minimum value was given by water-soaked control and it was at par with those for unsoaked control, 0.10% and 0.05%.

Table 44: Effect of pre-sowing seed treatment with pyridoxine on acid value, iodine value and saponification value of three varieties of mustard.

Seed treatments (% pyridoxine)	Acid value				Iodine value				Saponification value			
	Varieties											
	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean	RK-8203	PR-18	Varuna	Mean
Unsoaked control	3.67	4.22	2.69	3.53	99.73	96.60	98.99	98.44	164.00	134.30	144.10	147.47
Water-soaked control	3.29	4.69	2.71	3.56	100.18	93.77	99.58	97.84	168.00	137.00	148.50	151.17
0.0125	4.10	3.25	3.51	3.62	116.48	89.98	106.09	104.18	172.00	150.80	178.50	167.10
0.025	4.65	3.18	3.55	3.79	105.33	98.01	119.73	107.69	163.20	167.10	169.70	166.67
0.05	3.75	3.10	3.68	3.51	101.43	101.60	99.88	100.97	154.80	172.70	160.30	162.60
0.10	2.89	2.90	2.10	2.63	98.50	112.78	89.88	100.39	141.30	168.40	153.50	154.40
Mean	3.73	3.56	3.04		103.61	98.79	102.36		160.55	155.05	159.10	

N.B. A basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly at sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
Seed treatment (S)	N.S.	3.87	4.83
Variety (V)	N.S.	2.79	3.48
S x V	N.S.	N.S.	8.36

N.S. Non-significant

The effect was 9.1% less than 0.025% treatment which gave maximum value and differed critically from other treatments, except 0.0125%.

Significant lowest value was given by PR-18. RK-8203 and Varuna (being at par) gave maximum value.

4.4.5.2 Saponification value

The effect of seed treatment, varietal response and their interaction was found significant on this quality parameter.

Seed treatment 0.0125% gave maximum value which was at par with those for 0.025% and 0.05%. The increase due to 0.0125% was 10.5% in comparison with control. Unsoaked and water-soaked controls, being at par, gave lowest value.

RK-8203 gave maximum value which was statistically equal to that for Varuna. Significant lowest value was given by PR-18.

Regarding interaction effect, 0.0125' X Varuna gave maximum value which differed critically from other interactions, except 0.05 X PR-18 and 0.0125 X RK-8203. The minimum value was recorded in unsoaked control X PR-18 which was statistically equal to those for water-soaked control X PR-18 and 0.10 X RK-8203.

CHAPTER - 5

DISCUSSION

CONTENTS

DISCUSSION

DISCUSSION

5.1 Introduction

The productivity of a crop is an outcome of the interaction that operates between its genetic potential and the surroundings in which it is cultivated. These interactions constitute different isolated systems (acting synergistically with variable flexibilities) which regulate the entire course of crop development. Therefore, any disturbance in such system(s) results in poor performance of the crop. Interaction of soil atmosphere and root system of a crop is one of such systems. It is restricted by a definite influential zone called rhizosphere on the one hand and availability of nutrients and water on the other. Therefore, adequate absorption of nutrients and water (coupled with their proper absorption through roots) plays a crucial role in the life of a plant and helps in accomplishing its full genetic potential. Any impairment in this delicate relationship leads to ill consequences. The ideal situation for efficient functioning of this system may be accomplished either by additional supply of synthetic fertilisers, particularly of N, P and K, or by increasing the proliferation of root system in order to make it more efficient in exploring the soil. Ironically, soil-applied nutrients have limited advantage in maintaining the system as they usually become unavailable to plants due to fixation, leaching and volatalisation (Russell, 1950). The other option - that of proliferating root system - offers ample opportunity to plant physiologists to apply their skill. It has added advantage in curtailing the quantity of soil - applied nutrients leading to considerable fertiliser economy and the protection of environment against the menace of soil and water pollution.

At Aligarh, Afridi, Samiullah and their associates, working on these assumptions tried various growth substances to obtain luxuriant root system of various crops. They noted that among these substances, pyridoxine administered to seeds before sowing (or to a lesser degree when sprayed on standing crops at proper growth stages) enhanced not only root growth but also yield and quality of some creals and legumes (Afridi et al., 1979, 1985; Ahmad, 1975; Ahmad et al., 1981, 1982; Ashfaq et al., 1983; Khan and Ansari, 1984; Samiullah et al., 1985a; Ansari and Khan, 1986). However, oil - yielding crops were not included in this programme. Therefore, four field trials were conducted on mustard (*Brassica juncea* L. Czern. & Coss.) with a view to augmenting its performance so as to cope with the national demand for additional quantities of edible oil and, at the same time to achieve fertiliser economy. These experiments were conducted on the following lines:

1. To select a suitable locally adapted mustard variety through screening and to determining its optimum N and P requirement.

2. To test the efficacy of seed enrichment with pyridoxine in the selected variety.

3. To test the efficacy of pre-sowing pyridoxine treatment of this variety in achieving fertiliser economy.

4. To test the efficacy of pyridoxine in improving the performance of three mustard varieties.

5.2 Growth characteristics

Growth of plant organs results from orderly cell division, expansion and differentiation. These processes are dependent on proper supply of mineral nutrients (Moorley and Besford, 1983) and growth substances as well as on the genetic make up of the plants. A suitable combination of all these factors brings about healthy growth of plants and ensures good yield and quality of a crop.

In Experiments 1 and 3, fertiliser treatment significantly affected growth parameters (shoot length, leaf number, fresh weight and dry weight/plant) at all stages. Treatments $N_{60}P_{30}$ and $N_{60}P_{20}$ proved optimum in Experiments 1 and 3 respectively at most stages; while, in Experiment 1, shoot length was maximum in $N_{90}P_{30}$ at all stages.

Interestingly, in Experiment 3, top-dressing with nitrogen at 70d ($N_{60+30}P_{30}$) proved least effective. This could be the reason why top-dressing is not recommended for the cultivation of mustard. That $N_{90}P_{30}$ was also less effective than $N_{60}P_{20}$ for vegetative growth of this crop establishes the supra-optimal nature of the higher dose (Tables 7-10; 21-25).

None- the less, the essential role of nitrogen and phosphorus in crop growth and development is well established (Hewitt, 1963) and number of ~~farm~~ scientists, including Majumdar and Sandhu, 1963; Maini et al., 1963; Allen and Morgan, 1972; Naqvi et al., 1977; Mudholkar and Ahlawat, 1979; Singh et al., 1982 and Parvaiz et al., 1983 have recently reported beneficial effect of similar soil - applied nitrogen and phosphorus doses on growth characteristics of mustard.

In Experiment 2, pre-sowing seed treatment for 4h with 0.05% pyridoxine solution was found optimum for all growth characteristics at all three samplings. It may be admitted that it was the lowest concentration of pyridoxine tried and therefore, in subsequent studies (Experiment 3 and 4) concentrations lower than 0.05% were also included. Soaking the seeds in 0.0125% or 0.025% pyridoxine solution in Experiments 3 and 4 proved either optimum or at par for one or the other growth characteristic, indicating variable response of different growth parameters to pyridoxine treatment. In this context the findings of Ansari (1986), and Ansari and Khan (1986) with regard to pyridoxine may be cited which showed that various organs of leguminous crops, namely, *Lens culinaris* L. Medic and *Vigna radiata* L. Wilczek require different concentrations of pyridoxine for their proper growth and development. According to Thimann (1937), roots, buds and stems showed the requirement of different amounts of auxin for optimum growth and their may be a similar differential requirement of pyridoxine for growth of various organs of field grown mustard for which is a new finding. However, beneficial effect of pyridoxine has been reported for several other crops grown in sand culture (Murneek, 1941; Brusca and Hass, 1957; Barbeiri, 1959; Zavenyagina and Bukin, 1969; Afridi et al., 1979; Khan and Ansari, 1984 and in the field (Ansari and Khan, 1986).

Considering the performance of varieties (Experiment 1), Varuna proved best for all growth characteristics at three samplings, except for shoot length at 50 and 70d and leaf number at 70d, which were maximum in RK-8203 and Pusa Bold respectively. In fact, Varuna has been well established as the best suited variety of mustard for the region for more than a decade on the basis of seed yield and oil quality by Samiullah et al. (1983), Mohammad (1984) and Mohammad et al. (1984), but these studies did not include comparison of the vegetative growth of Varuna with those of other varieties. For this very reason, Varuna itself as the best adapted among other varieties in Experiment 1 was included in all the three subsequent experiments, In Experiment 4, however, PR-18 that closely followed Varuna, and RK-8203 a poor yielding variety of Experiment 1 were included with a view to compare their response with that of Varuna to pyridoxine treatment.

Various interactions, e.g.,fertiliser treatment X variety, seed treatment X fertiliser treatment and seed treatment X variety (Experiments 1,3 and 4 respectively) were found to affect vegetative growth significantly (Tables 7-10; 21-25; 33-37). As far as interaction of fertiliser treatment X variety is concerned, there was a variable response of different parameters, For example, Varuna gave maximum leaf number with $N_{60}P_{30}$ or $N_{90}P_{30}$ at 50 and 90d and dry weight at all the stages. While RK-1467 X $N_{60}P_{30}$, $N_{90}P_{30}$ or $N_{60}P_{30}$ produced highest fresh weight at 50, 70 and 90d respectively. On the other hand shoot length at 50 and 70d was noted to be maximum in RK-8203 X $N_{60}P_{30}$. In addition, combination $N_{60}P_{30}$ X PR-18 also gave at par values with Varuna X $N_{60}P_{30}$ and Varuna X $N_{90}P_{30}$ for leaf number at 90d and dry weight at 50 and 70d. The other combinations of these varieties were either at par with each other or closely followed the best interactions. Such a differential response of varieties to mineral nutrients was expected as they differ in their genetic make up and nutrient requirement. However, there is no report of such studies in the literature on mustard. In Experiment 3, 0.025 X $N_{90}P_{30}$, 0.025 X $N_{60}P_{20}$ and 0.0125 X $N_{60}P_{20}$ (being at par) gave maximum values for almost all growth parameter. In fact, this trial was conducted to assess the efficacy of soaking in dilute pyridoxine solution in bringing about fertiliser economy. This seems to be substantially established as soaking elicited equally good response at both high and low fertiliser levels. Probably, soaking in pyridoxine solution facilitated root growth, providing larger surface area to absorb nutrients (and water) more readily from the soil. Therefore, roots of treated plants would have made full use of the applied low fertiliser dose ($N_{60}P_{20}$). This view draws support from the observation of equal leaf NPK accumulation in plants grown from treated seeds irrespective of their receiving high or low doses which will be discussed in Section 5.4. In this respect, it may be emphasised that pyridoxine has been well established as a growth promoting substance in the case of excised roots of various plants in vitro (Bonner and Bonner, 1948; Åberg, 1961) as well as for root growth of cereals and legumes in sand culture and under field conditions (Afridi et al., 1979; Khan and Ansari, 1984; Samiullah et al., 1985a; Ansari, 1986).

In Experiment 4, combination 0.0125 X Varuna and 0.05 X RK-8203 gave maximum values for almost all growth parameters. While, PR-18 with all seed treatments resulted in inferior vegetative performance (Tables 33-37). It is interesting to note that RK-8203 which performed poorest in Experiment 1 came up abreast with Varuna on receiving pyridoxine seed treatment but required higher concentration of pyridoxine than Varuna. Contrarily, PR-18, following Varuna in Experiment 1, showed negative response to pyridoxine seed treatment. It may be due to different amount of native pyridoxine in their seeds which was in the order : PR-18 (26.79 μg/g) > Varuna (19.12 μg/g) > RK-8203 (10.28 μg/g). It seems likely that soaking of RK-8203 seeds in pyridoxine solution enhanced endogenous level of this vitamin to an extent that might have helped it to come at par with Varuna, while treatment of PR-18 seeds resulted in endogenous pyridoxine accumulation to the extent of inhibition which was presumably responsible for its poor performance. Therefore, pyridoxine content of the seeds may be taken as a major criterion to decide whether particular variety (ies) of a crop will respond to vitamin treatment or not. Similar conclusion was drawn by Ansari (1986) in connection with the performance of leguminous crops in relation to pre-sowing seed treatment with pyridoxine.

5.3 Net assimilation rate (NAR)

As nine-tenth of the dry weight of a plant arises directly from photosynthesis, it was considered desirable to explore the effects of the applied nutrients and vitamin and of the genetic variability of crop varieties as well as of their interactions on growth rates in terms of the size of the photosynthesising surface (taken as the mean area of leaves) and intensity or efficiency at which each unit of leaf functions (Milthorpe and Moorby, 1979). This efficiency is usually determined by computing NAR values which reflect direct relationship with the yielding ability of a crop. Therefore, NAR was calculated for 50-70d and 70-90d periods in all experiments.

In Experiment 1 and 3, combined application of nitrogen and phosphorus ($N_{60}P_{20}$) gave highest leaf NAR values at both intervals but $N_{60}P_{30}$ also proved at par with it at both interval in Experiment 1 (Tables 11;26). It may be recalled that most of the growth parameters, including dry weight and leaf number were also noted to be maximum in the same fertiliser treatment (p.127). This the beneficial effect of applied nutrients might have been manifested in the NAR values. It may be reiterated that information about the NAR response of mustard to combined nitrogen and phosphorus application is not available in the literature. However, Allen and Morgan (1972) did not find any effect of nitrogen on NAR of mustard. In the present study, $N_{60}P_{20}$ seems to be the most balanced fertiliser dose with nitrogen and phosphorus acting synergistically in enhancing leaf number and dry matter accumulation (Tables 8;10;23;25) which seems to have resulted subsequently in the highest NAR value. This view is further substantiated by the fact that further application of nitrogen by top-dressing (Experiment 3) proved deleterious, presumably due to the nutrient combination becoming unbalanced.

Soaking in 0.05, 0.025 and 0.0125% pyridoxine solution resulted in maximum NAR values in Experiments 2, 3 and 4 (Tables 17;26;38) respectively which is in accordance with the response of different growth parameters as discussed on p.127 particularly leaf number and dry weight. No studies have been made on the response of mustard NAR to pyridoxine application. However, Ansari (1986) and Ansari and Khan (1986) noted enhancement in the NAR values at different time intervals in the case of _Lens culinaris_ and _Vigna radiata_ as a result of pre-sowing seed treatment with pyridoxine.

In Experiments 1 and 4, variety Varuna exhibited maximum NAR values at both intervals. However, Pusa Bold in Experiment 1 and RK-8203 in Experiment 4 proved at par with Varuna (Tables 11; 38). These variations in NAR values among different mustard varieties are expected as NAR may vary within species. For example, small but significant differences have been found between varieties of potatoes, and high sugar content strains of sugar beet appear to have a higher NAR than strains bred for high yield (Boonstra, 1939; Watson, 1947). Similarly, cacao seedlings grown from the progeny of four trees differed in NAR during the early stages of growth (Goodall, 1950). Thus, the existence of intraspecific differences in NAR is well established.

As far as interactions are concerned, $N_{90}P_{20}$ X Varuna at 50-70d and $N_{90}P_{30}$ X Varuna at 70-90d proved best for NAR in Experiment 1 (Table 11). However, $N_{60}P_{30}$ X PR-18 also gave NAR value equal to those for $N_{90}P_{30}$ X Varuna at 50-70d period and $N_{90}P_{30}$ X Varuna at 70-90d. It might be a manifestation of the beneficial effect of these interactions on leaf number and dry weight of plant. In Experiment 3, 0.025 X $N_{90}P_{30}$, 0.025 X $N_{60}P_{20}$ and 0.0125 X $N_{60}P_{20}$ (being at par) gave maximum value for NAR at both intervals. While top-dressing of nitrogen did not affect NAR. As discussed on p.136 soaking of seeds in pyridoxine helped in enhanced uptake of nutrients (Tables 27-29) due to the development of efficient root system (Table 22), which might have been subsequently assimilated as a result of higher photosynthesis (dry matter production), with the help of increased leaf number noted in the same interactions (Tables 23; 25). Moreover, in Experiment 4, 0.0125 % Varuna gave maximum value at both interval. However, it is interesting to note that, inspite of poor growth performance of RK-8203 in Experiment 1 (Tables 7-10), soaking the seeds of this variety in 0.05% pyridoxine solution helped in improving photosynthetic ability of the variety to such an extent that it became at par with Varuna at the later interval (Table 38). It may be due to the fact that pyridoxine administration to the seeds made up for their low endogenous level of pyridoxine (p.131) promoting differentiation and development of more leaves. This could result in more dry matter accumulation and consequently high NAR.

Lastly, the decrease in NAR at later interval in all experiments may be due to increase in leaf number with the growth of plants (Tables 11; 17; 26; 38) to such an extent that it might have resulted in mutual shading of leaves preventing maximum harvesting of solar radiation with consequent decrease in the amount of photosynthetes formed (Milthorpe and Moorby, 1979).

5.4 Leaf NPK content

Leaf analysis is considered as an index of the mineral status of the soil as well as the indication of mineral requirements of the plant (Lundegårdh, 1943; 1947; 1951). Leaf nutrient content has been established to be correlated with vegetative as well as reproductive growth of crop plants (Lundegårdh, 1951; Inam et al., 1982; Akhtar, 1985). Therefore, leaf NPK content was estimated at three growth stages in the present study in response to combined application of nitrogen and phosphorus, soaking the seeds in pyridoxine and genetic variability as well as to their interactions.

Application of N and P significantly affected leaf nutrient content in Experiment 3, $N_{60}P_{20}$ proving maximum for leaf N content at 50 and 70d, leaf P content at 70 and 90d and leaf K content at 50d. However, it was equalled by 30 kg top-dressing of N in case of leaf N and K at 50d and leaf P content at 90d as well as by $N_{90}P_{30}$ in case of leaf N and P contents at 70d (Tables 27-29). These findings further correborate the earlier expressed view that $N_{60}P_{20}$ is a balanced dose for mustard, and top-dressing/high basal dose of nitrogen is ineffective as has been discussed earlier (p.127). Enhanced leaf NPK content may be due to greater uptake of these nutrients from the soil as a result of better root growth and root-shoot ratio caused by combined application of N and P. However, such studies have not been conducted on mustard in relation to soil-applied nutrients, except by Mehrotra et al. (1972) who noted that application of N and P results in high N and P content in the aerial parts of mustard at various growth stages upto harvesting.

Soaking in 0.05% pyridoxine solution in Experiment 2, 0.025% in Experiment 3 as well as 0.0125 and 0.025% (both proving at par in their effect) in Experiment 4, enhanced leaf NPK content at all growth stages, except leaf K at 90d in Experiments 3 and 4 which was non-significant (Tables 18;27-29;39-41). Ovcharvo and Kulieva (1968) also reported higher content of nitrogen and phosphorus in 48h old cotton seedlings as a result of soaking of seeds in pyridoxine. Similar enhanced leaf NPK contents were noted in Lens culinaris and Vigna radiata under field conditions by pre-sowing seed treatment with pyridoxine (Afridi et al., 1985; Ansari, 1986). Moreover, facilitated uptake of nitrogen and phosphorus in Mentha piperita and of several elements, including NPK, in Vigna radiata seedlings was observed with B-vitamin treatments including thiamine, pyridoxine and nicotinic acid (Dimitrova-Russeva and Lilova, 1969; Gopala Rao and Raghava Reddy, 1985). However, there is no report indicating the effect of pyridoxine on leaf NPK content in mustard.

Among varieties,Varuna exhibited highest leaf NPK content in Experiment 4 at three growth stages except leaf K at 70d (when it was equalled by RK-8203) and at 90d when it was non-significant (Tables 39-41). Such differential response of various cultivars in respect of leaf NPK is expected as absorption and assimilation of nutrients depend on the genetic constitution of the crop.

Regarding interaction effect in Experiment 3, 0.025 X $N_{60}P_{20}$ gave maximum value for leaf NPK content at all stages, except leaf N at 90d and leaf K at 70 and 90d (non-significant). However, its effect was equalled by 0.025 X $N_{90}P_{30}$ on leaf NPK content at most of the growth stages and by top-dressing of 30 kg N with 0.025% soaking treatment on leaf N and K at 50d and leaf P at all three stages (Tables 27-29). In fact, accumulation of nutrients in leaves corresponds linearly to soil-applied nutrients until they become supra-optimal. This situation in the present investigation seems to be achieved with $N_{60}P_{20}$. On the other hand application of nitrogen above N_{60}, applied either as basal dose or through supplemental top-dressing, had presumably become supra-optimal. Besides, it may be possible that pre-sowing seed treatment with pyridoxine resulted in a well developed root system (Table 22) which subsequently enabled the plants to utilise $N_{60}P_{20}$ efficiently. Moreover, in Experiment 4, 0.0125 X Varuna gave maximum value at all growth stages, except leaf N content as 50d (maximum in 0.025 X Varuna) and leaf K at 70 and 90d (non-significant). It may be noted that the interaction 0.05 X RK-8203 proved at par with 0.0125 X Varuna for leaf N content at 50d and leaf P at all three stages (Tables 39-41). As discussed on p. it seems that increased endogenous level of pyridoxine as a result of seed treatment enhanced the absorbing capacity of roots of mustard varieties, particularly RK-8203 which showed improved absorption of N and P at certain stages of growth as efficiently as Varuna. However, the exact role of pyridoxine in nutrient uptake is not known, though Ansari (1986), assumed that pyridoxine treatment altered the permeability of root cell memberances or facilitated the activity of membrane bound carrier proteins favouring high uptake of nutrients; but this assumption needs to be verified experimentally.

In the present study, the leaf NPK contents in all experiments declined as plants advanced in age. The situation arises partly due to an exponential increase in growth (weight and volume) of plants as a result of which even high quantities of nutrients seem to be less when expressed on per unit basis- the so-called "dilution with growth" effect (Moorley and Besford, 1983; Anonymous, 1984). Besides, translocation of nutrients to sinks during and after pod formation could also deplete leaf nutrient content. Similar depletion in leaf NPK content as the plant matured has been reported in several crops grown at Aligarh (Safaya, 1970; Samiullah, 1971; Khalique, 1975; Naqvi, 1976; Abbas, 1980; Inam et al., 1982; Abbas et al., 1983; Samiullah et al., 1984; Akhtar, 1985; Ansari, 1986; Akhtar et al., 1987; Moinuddin, 1987).

5.5 Yield characteristics

Yield is the final manifestation of several complex morphological and physiological traits of a crop. According to

Yoshida (1972) "a high yield of any crop can be achieved only when a proper combination of variety, environment and agronomic practices is obtained. Understanding the physiological processes involved in seed production such as vegetative growth, formation of storage organs, and seed filling helps determine the best combinations of the above three factors".

Fertiliser treatment $N_{60}P_{20}$ proved optimum for seed yield, oil content and oil yield in Experiments 1 and 3 (Tables, 13; 31, Figs. 1,3) producing 5.3% higher seed yield than that of higher dose ($N_{90}P_{30}$) in Experiment 1 and 1.4 and 3.8% more seed yield than $N_{90}P_{30}$ and $N_{60+30}P_{30}$ respectively in Experiment 3. In Experiment 3, $N_{60}P_{20}$, produced 3.6 and 8.0% higher oil yield than $N_{90}P_{30}$ and $N_{60+30}P_{30}$ respectively. This was expected as the yield parameters, including pods/plant, seeds/pod and hecto-litre weight in Experiment 1 were also maximally enhanced by the same fertiliser dose. Moreover, various growth parameters and NAR in both experiments as well as leaf NPK contents in Experiment 3 responding optimally to $N_{60}P_{20}$ support the view that yield of a crop is determined by its overall performance during vegetative and reproductive phase of life. On the other hand, in Experiment 3, low hecto-litre weight of seeds in $N_{60}P_{20}$ compared to that in the higher dose, i.e., $N_{90}P_{30}$ or in supplemental top-dressing of 30 kg N, seems to be due to the larger number of pods and seeds/pod noted in the $N_{60}P_{20}$ which resulted in the distribution of photosynthates among more sinks (seeds) - a "dilution effect" phenomenon. The improvement

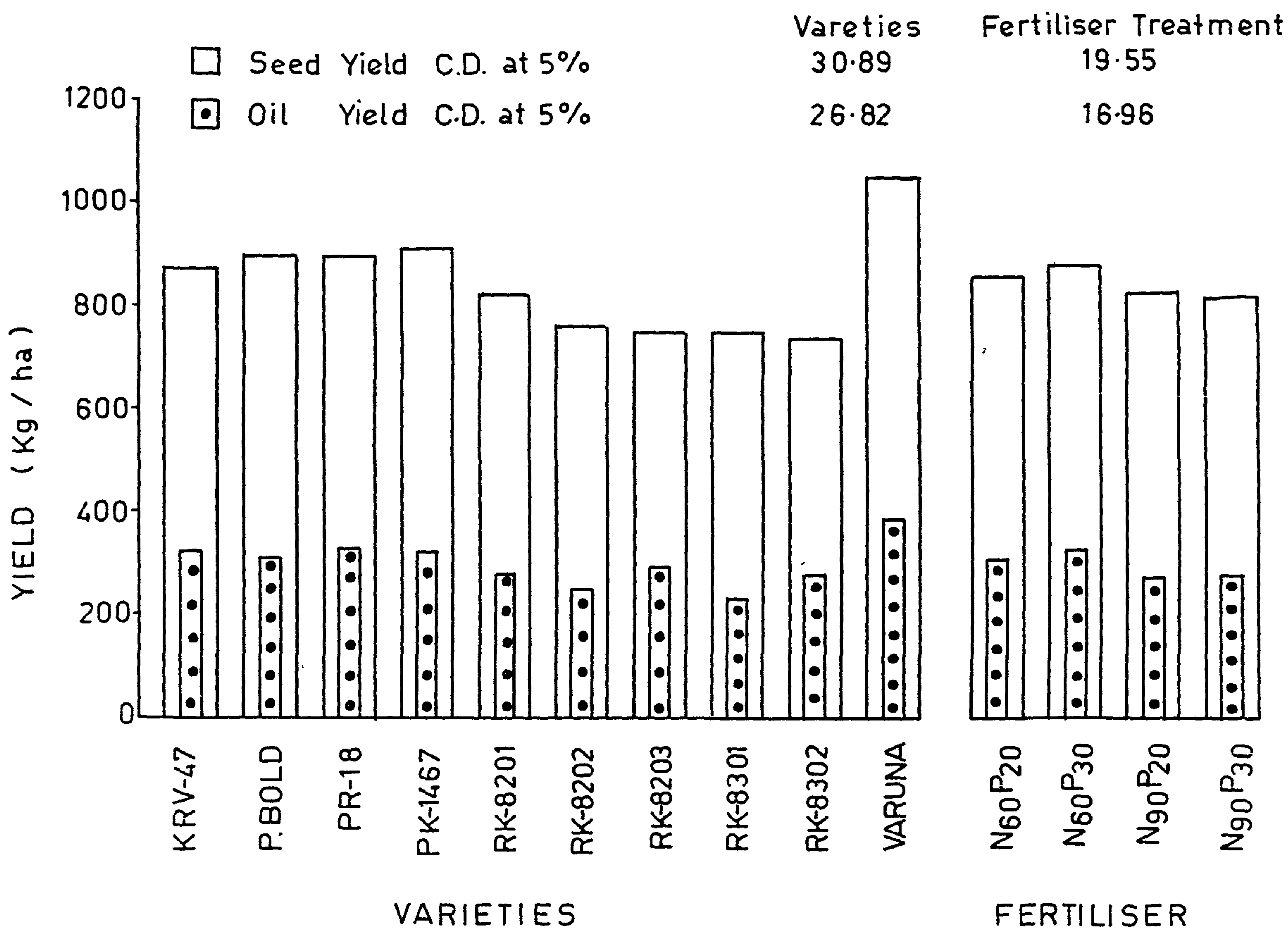

Fig.1. Effect of selected combinations of nitrogen and phosphorus on seed yield and oil yield of ten varieties of mustard.

in seed yield of mustard by the application of N and P alone or in combination has also been reported by many workers, including Stepanova (1958), Pathak *et al*. (1961), Beech and Norman (1964), Anderson and Kusch (1968), Dembinski *et al*. (1969), Lammerink and Morice (1970), Rollier (1970a,b), Singh *et al*. (1971), Mehrotra *et al*. (1972), Chundawat *et al*. (1975), Pérez and Mora (1975), Bhan and Singh, (1976), Sotomayor (1977), Henry and Macdonald (1978), Holmes and Ainsley (1978), Parvaiz (1980), Parvaiz *et al*. (1982), Afridi *et al*. (1983), Parvaiz *et al*. (1983), Samiullah *et al*. (1983), Mohammad *et al*. (1984) Samiullah *et al*. (1984), Mohammad *et al*. (1985) and Samiullah *et al*. (1985b). The deleterious effect of high nitrogen doses on oil content noted in the present study broadly confirms the findings of earlier workers (Arora and Bhatia, 1970; Rollier, 1970a,b; Kolosova, 1972; Dasgupta and Friend, 1975; Mazur *et al*., 1977; Holmes and Ainsley, 1979; Holmes and Bennett, 1979; Parvaiz, 1980; Parvaiz *et al*., 1982; Afridi *et al*., 1983; Samiullah *et al*., 1983; Mohammad *et al*., 1985). Similarly, increase in oil yield by basal application of nitrogen and phosphorus has been obtained by several workers at Aligarh (Parvaiz, 1980; Parvaiz *et al*., 1982; Afridi, *et al*., 1983; Parvaiz *et al*., 1983; Samiullah *et al*., 1983; Samiullah *et al*., 1984; Mohammad *et al*., 1984 and Samiullah *et al*., 1985b).

Seed treatment with 0.05%, 0.025% and 0.0125% pyridoxine proved best for yield (Figs. 2;3;4) and it's attributing characters in Experiments 2, 3 and 4. There was enhancement of seed yield

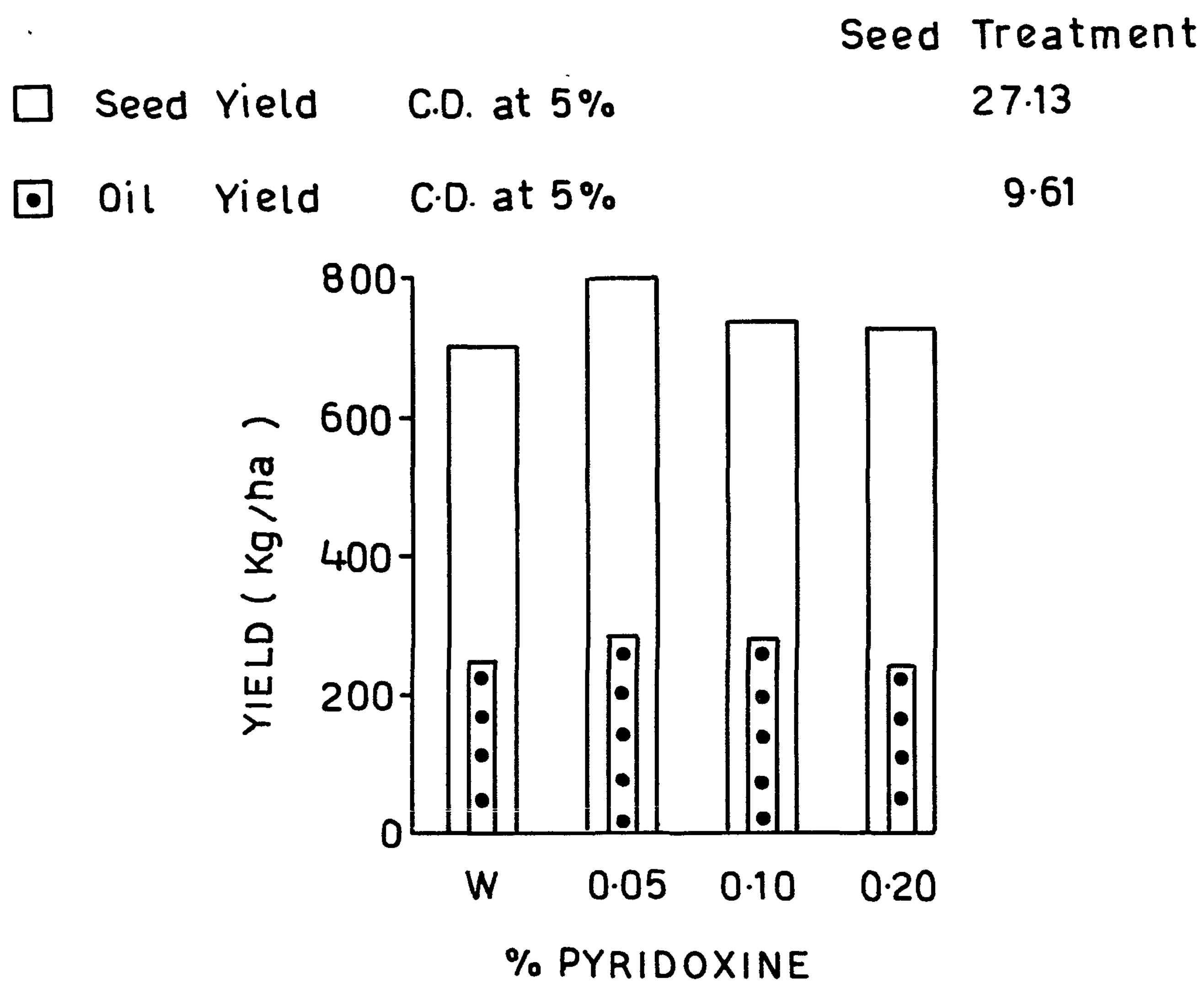

Fig.2. Effect of pre-sowing seed treatment with pyridoxine on seed yield and oil yield of mustard variety Varuna.

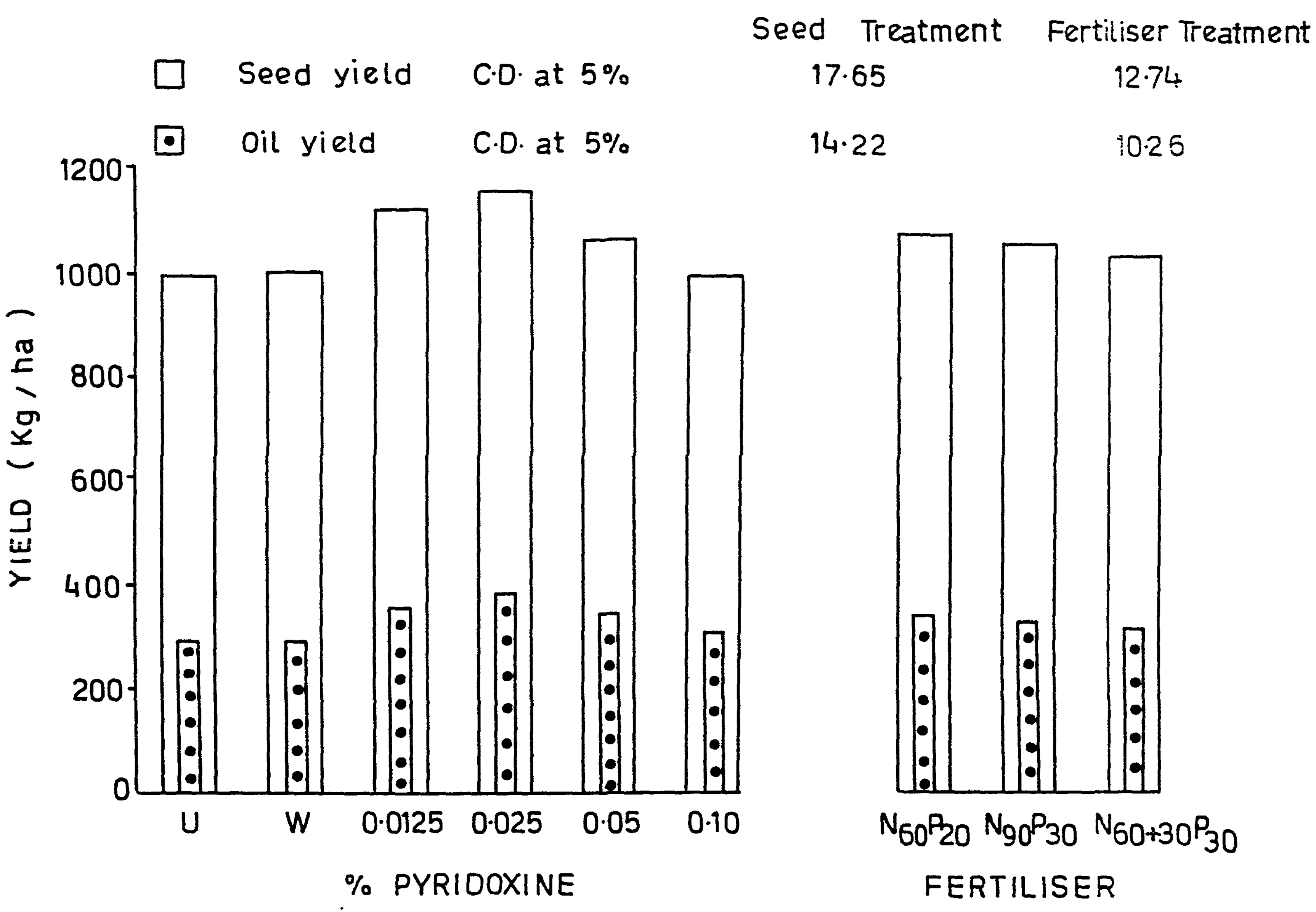

Fig.3. Effect of pre-sowing seed treatment with pyridoxine and selected combinations of nitrogen and phosphorus on seed yield and oil yield of mustard variety Varuna.

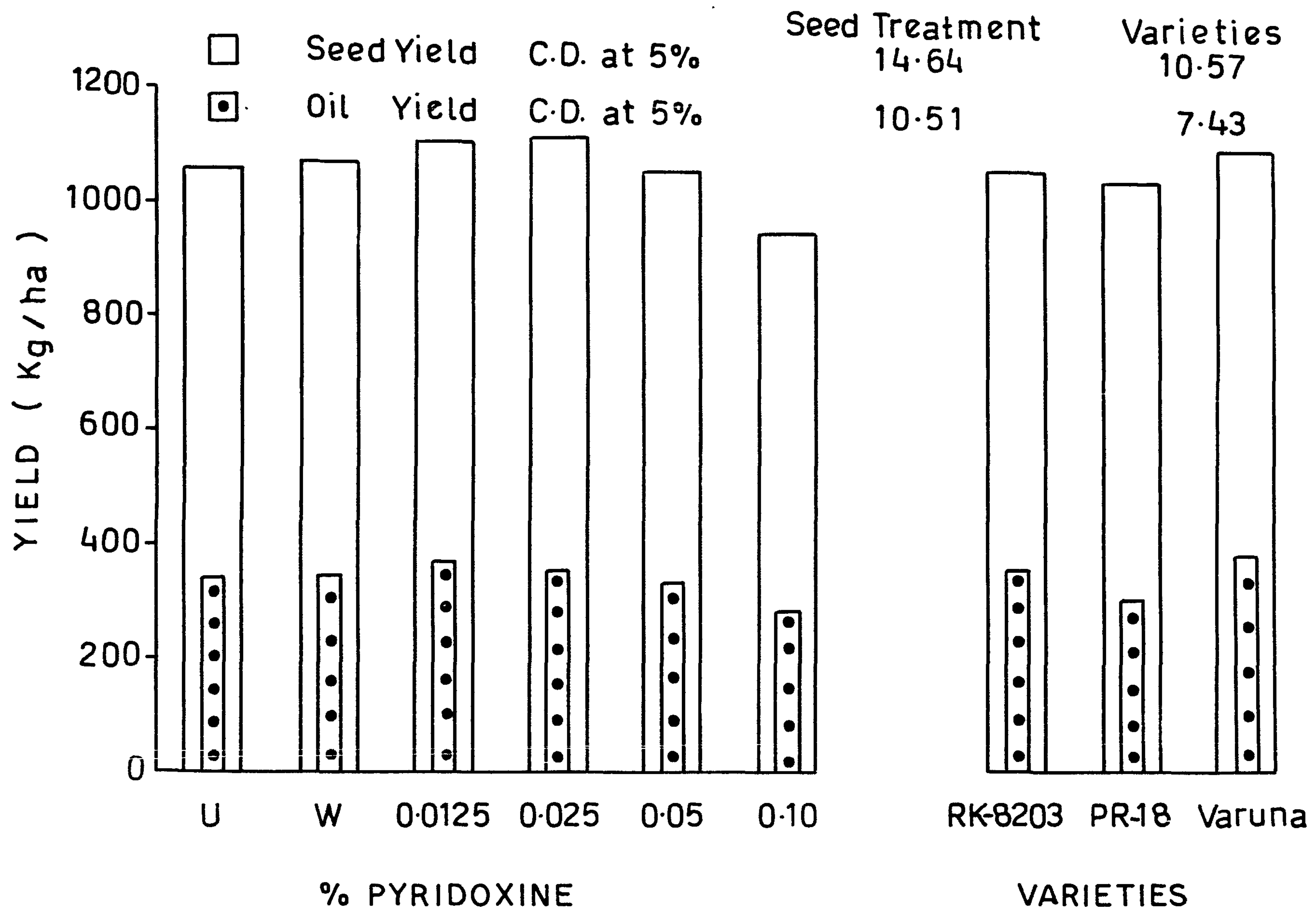

Fig.4. Effect of pre-sowing seed treatment with pyridoxine on seed yield and oil yield of three varieties of mustard.

and oil yield by 13.8 and 16.7% due to 0.05% in Experiment 2, 14.9 and 33.3% due to 0.025% in Experiment 3 and 3.2 and 8.0% due to 0.025% over water-soaked control in Experiment 4. Such a beneficial effect of pyridoxine on productivity and quality of cereals and legumes has also been reported by other workers from the author's laboratory (Afridi et al., 1979; 1985; Ahmad et al., 1981, 1982; 1986a,b; Ashfaq et al., 1983; Samiullah et al., 1985a; Ansari, 1986). As mentioned earlier, the same treatments had also proved optimum for most of the growth characteristics, NAR and leaf NPK contents. It clearly indicates that the cumulative effect of these parameters resulted in enhanced seed yield and oil yield of mustard (Figs. 2,3). This view obtains support by the correlation co-efficients having been worked out between these parameters and seed yield in Experiment 4 (Table 45). However, low hecto-litre weight in Experiment 4 and oil content in Experiment 2 noted in 0.0125 and 0.10% pyridoxine solution respectively seems to be due to dilution effect discussed on p.140 . Further enhancement in mustard oil production by pre-sowing seed treatment with pyridoxine seems to have been favoured by the synthesis of mustard oil precursor amino acids, i.e., glutamate, aspartate, alanine or serine (Mengel and Kirkby, 1982, p.378) at the expense of α-keto acids produced during Kreb's cycle due to the well established role of pyridoxine as co-enzyme in various amino transferase system (Lehninger, 1982). It thus opens up a new avenue and detailed investigation of the role of

Table 45: Correlation of various parameters with seed yield of RK-8203, PR-18 and Varuna varieties of mustard (n = 18).

Parameters	Days	Correlation coefficient (r)		
		RK-8203	PR-18	Varuna
Shoot length	50	0.593**	0.612**	0.738**
	70	0.796**	0.613**	N.S.
	90	0.781**	0.763**	0.802**
Root length	50	0.814**	0.659**	0.724**
	70	0.803**	0.726**	0.703**
	90	0.799**	0.815**	0.512*
Leaf number	50	0.645**	0.686**	0.816**
	70	N.S.	0.715**	0.513*
	90	0.736**	0.698**	0.731**
Fresh weight	50	0.879**	0.839**	0.663**
	70	0.866**	0.681**	0.837**
	90	0.481*	0.608**	N.S.
Dry weight	50	0.609**	0.651**	0.726**
	70	0.681**	0.611**	0.814**
	90	0.734**	0.603**	0.801**
Net assimilation rate	50-70	0.613**	0.794**	0.615**
	70-90	0.636**	0.798**	0.713**
Leaf nitrogen content	50	0.668**	0.717**	0.791**
	70	0.691**	0.618**	0.624**
	90	0.762**	0.691**	0.738**
Leaf phosphorus content	50	0.756**	0.737**	0.516*
	70	0.673**	0.652**	0.834**
	90	0.759**	0.515*	0.658**
Leaf potassium content	50	0.814**	0.635**	0.836**
	70	0.586*	0.510*	N.S.
	90	N.S.	N.S.	N.S.
Pods/plant	120	0.862*	0.738**	0.697**
Seeds/pod	120	0.693**	0.659**	N.S.
Hecto-litre weight	120	0.717**	0.748**	0.798**

* Significant at $p < 0.05$; ** Significant at $p < 0.01$;
N.S. Non-significant.

pyridoxine in mustard oil synthesis could be a rewarding exercise as this has not been studied yet.

Among varieties, Varuna outyielded other varieties in Experiments 1 and 4 (Tables 13;43; Figs.1;4).Varuna registered 38.7% more seed yield than RK-8203 (the lowest yielder) and 66.2% higher oil yield than RK-8301 and 31.9% than RK-8203 in Experiment 1. In Experiment 4, Varuna gave 3.0 and 5.5% higher seed yield and 2.3 and 17.0% higher oil yield than RK-8203 and PR-18. It may be recalled that Varuna was also excellent in almost all growth parameters. Besides, Varuna also excelled other varieties in Experiments 1 and 4 in yield attributing characters, except hecto-litre weight in Experiment 4 that was optimum in RK-8203. But seeds/pod in KRV-47 (Experiment 1) and in RK-8203 (Experiment 4) were at par with that in Varuna. These findings confirm that both vegetative and reproductive growth contribute cumulatively to seed yield. Correlation studies undertaken in Experiment 4 also bear testimony to this fact. However, degree of strong correlation ($p < .01$) followed the order : PR-18 $\gtrsim$ RK-8203 $>$ Varuna and seeds/pod in Varuna proved to be a non-contributing character to seed yield (Table 45). Surprisingly, there is no report in the literature indicating correlation between vegetative and reproductive growth and seed yield in mustard, despite the fact that such relationship provides a reliable assessment of yield performance as well as an opportunity to take corrective measures at an early growth stage.

Considering fertiliser treatment X variety interaction in Experiment 1, $N_{60}P_{30}$ X PR-18, $N_{60}P_{30}$ X RK-1467 and $N_{90}P_{30}$ X Varuna resulted in maximum seed and oil yields. However, RK-8203 with $N_{90}P_{30}$ and $N_{60}P_{30}$ and KRV-47, RK-8302 and Varuna with $N_{60}P_{20}$ gave maximum oil content (Table 13). It is interesting to note that only Varuna with $N_{90}P_{30}$ and $N_{60}P_{20}$ resulted in maximum pods/plant and hecto-litre weight respectively (Table 12). However, enhanced seed and oil yield in $N_{60}P_{30}$ X PR-18 and $N_{60}P_{30}$ X RK-1467 (and also in $N_{90}P_{30}$ X Varuna) seems to be a reflection of excellent vegetative growth noted in these interactions. The findings establish that whereas Varuna is a high nutrient requiring variety, PR-18 and RK-1467 are low fertiliser requiring cultivars. Among seed treatment X fertiliser treatment interactions, 0.025 X $N_{90}P_{30}$, 0.025 X $N_{60}P_{20}$ and 0.0125 X $N_{60}P_{20}$ (being at par) proved optimum for pods/plant and seed and oil yields (Tables 30-31) in Experiment 3. It may be noted that the same interactions also resulted in maximum vegetative growth, NAR and leaf NPK contents at various growth stages. Moreover, 0.025 X $N_{90}P_{30}$ and 0.025 X $N_{60}P_{20}$ resulted in optimum oil content while 0.025 X $N_{90}P_{30}$ and 0.0125 X $N_{60}P_{20}$ produced most seeds/pod. This indicates that soaking in pyridoxine helped curtail the input of fertiliser without reducing seed and oil yields. In Experiment 4, 0.0125 X Varuna gave maximum value for pods/plant, seeds/pod, hecto-litre weight, seed yield, oil content and oil yield. However, the combination was equalled by 0.05 X RK-8203 in seeds/pod, hecto-litre weight and seed yield; by 0.025 X RK-8203 in hecto-litre weight and 0.0125 X RK-8203, 0.025 X RK-8203 and 0.025 X Varuna in oil content. A somewhat similar trend was noted in vegetative growth, NAR and leaf NPK contents. Therefore pre-sowing treatment with 0.0125% pyridoxine to Varuna seeds with lower fertiliser dose, i.e., $N_{60}P_{20}$ may ensure seed and oil yields as high as with high fertiliser dose, i.e., $N_{90}P_{30}$, saving 30 kg N and 10 kg P/ha. Moreover, seed enrichment of RK-8203 with 0.05% pyridoxine treatment improves its seed and oil yield performance considerably. The observation that variety PR-18 interacted poorly with pyridoxine treatments of its seed could be explained on the basis of its highest native seed pyridoxine content (p.131). The pre-sowing seed treatment apparently increased this pyridoxine quantity to inhibitory levels.

5.6 Quality characteristics

For assessing oil quality, acid, iodine and saponification values were determined in all experiments. It may be added that low acid and iodine value are considered good for oil quality and denote good keeping and easy hydrogenation. High soponification value is good for digestibility or soap making quality. Among fertiliser treatments, $N_{60}P_{30}$ and $N_{90}P_{30}$ (being at par) showed minimum value in Experiment 1 and $N_{60}P_{20}$ produced maximum saponification value in Experiment 1 and 3 (Tables 14; 32). Decrease in iodine value with increasing doses of nitrogen has been noted by several workers including Arora and Bhatia (1970), Samiullah et al. (1983); Mohammad (1984) and Mohammad et al. (1985) in mustard and by Khan and Gupta (1959), Dybing (1964), Yermanos et al. (1964) and Singh and Singh (1978) in linseed. However, high saponification value together with high seed and oil yield in $N_{60}P_{20}$ seems to be a plus point as high value of this parameter facilitates its digestion.

Considering seed treatment, control and 0.2% treatment (being at par) in Experiment 2 proved best for iodine value and 0.05% treatment for saponification value. On the other hand 0.0125% and 0.025% seed treatment (being at par) gave maximum value for saponification value (Experiment 3 and 4). Lowest iodine value in Experiment 4 was registered with control. The role of pyridoxine in regulating these parameters is not known. However, it seems logical to assume that pyridoxine acting as co-enzyme for amino-transferase altered C/N ratio in a way that favoured the synthesis of short chain unsaturated fatty acids (being denoted by high saponification and iodine value). This assumption finds an indirect support from the findings of Dasgupta and Ghosh (1977) who noted a chain elongation from oleic ($C_{18:1}$) to erucic acid ($C_{22:1}$) as a reult of carbon skeleton formation due to increased supply of nitrogen.

Regarding varieties, RK-8201, and KRV-47 (being at par) gave minimum acid value in Experiment 1. However, in Experiment 4, iodine value was best in PR-18 and saponification values in RK-8203 and Varuna, both being at par. On the other hand, Varuna gave minimum iodine value and RK-8202 and Varuna (being at par) high saponification value in Experiment 1 (Tables 14;44). It indicates that the oil of Varuna is endowed with easy hydrogenation and digestibility although it had poor keeping quality. However, the production of mustard oil in the country is so low that it cannot cope with the domestic demands. Therefore, there is little chance of mustard oil being stored for a long period. In other words, the oil obtained from Varuna is of fairly good quality.

Considering interactions, iodine value in Experiment 1 and saponification value in Experiment 1, 3 and 4 was significantly, affected. The combination, $N_{90}P_{30}$ X RK-8302 gave significantly lowest iodine value, and $N_{60}P_{20}$ X Varuna, $N_{60}P_{20}$ X RK-1467, $N_{60}P_{20}$ X RK-8202, $N_{60}P_{30}$ X Varuna, $N_{90}P_{20}$ X Varuna, $N_{60}P_{20}$ X PR-18 and $N_{60}P_{20}$ X RK-8301 (all being at par) high saponification values in Experiment 1 (Table 14). In Experiment 3, 0.0125 X $N_{60}P_{20}$, 0.025 X $N_{60}P_{20}$, 0.0125 X $N_{60+30}P_{30}$, 0.025 X $N_{60+30}P_{30}$, 0.025 X $N_{90}P_{30}$ and 0.0125 X $N_{90}P_{30}$ gave statistically equal and maximum saponification values (Table 32). On the other hand, in Experiment 4, 0.0125 X Varuna, 0.05 X PR-18 and 0.0125 X RK-8203 (being at par) gave highest saponification value (Table 44). The effect of such interactions on oil quality, including acid, iodine and saponification value has not been studied so far. However, these findings reveal that oil quality varies with fertiliser doses, seed treatment and varietal differences.

The influence of seed treatment on oil quality seems to be a 'carry over' effect being operative during the entire life of the plant. The exact mechanism by which various factors interact to regulate the oil quality needs to be thoroughly investigated so that it may become possible to improve mustard oil quality through a well planned judicious combination of these factors by proper scientific manipulation.

5.7 Conclusion

In the end it may be concluded that :

(1) of the 10 new varieties, Varuna and PR-18 proved to be the best yielders, but they showed differential fertiliser requirements. Thus, Varuna could be cultivated profitably with $N_{90}P_{30}$ while PR-18 responded equally well to $N_{60}P_{30}$ (Experiment 1).

(2) the fertiliser requirement of variety Varuna could be cut down by pre-sowing seed treatment with economical dilutions of aqueous pyridoxine solution. 30 kg N and 10 kg P/ha could be saved by this technique, taking as low a dose of pyridoxine as 0.0125% (Experiments 2 & 3).

(3) the growth and yield of a variety of mustard could depend on the native pyridoxine level of its seed (Experiment 4) which may be taken as a dependable criterion to judge its performance.

(4) the yielding ability of poor yielders (with low native seed pyridoxine content like RK-8203) could be enhanced considerably by pre-sowing seed treatment with requisite dilute pyridoxine solution.

CHAPTER - 6

SUMMARY

SUMMARY

The importance of the problem "Productivity of Mustard in Relation to Mineral Nutrition and Pyridoxine Application" has been discussed briefly. In view of the lacunae in the understanding of the problem, justifications have been put forward for undertaking the present work (Chapter 1).

The literature pertaining to mineral nutrition and vitamin application has been reviewed (Chapter 2).

The details of the material and methods employed for the four field experiments have been given with the relevant meteorological and edaphic data (Chapter 3).

The results mostly found significant at $p < 0.05$ on statistical analysis according to the design of each experiment, have been recorded in detail (Chapter 4).

The main results have been discussed in the light of the findings of earlier researchers in our laboratory and elsewhere (Chapter 5) and are summarised below:

Experiment 1 (1983-84) was conducted according to factorial randomised block design to study the performance of ten mustard varieties, namely, KRV-47, Pusa Bold, PR-18, RK-1467, RK-8201, RK-8202, RK-8203, RK-8301, RK-8302 and Varuna under two levels of nitrogen (60 and 90 kg N/ha) and phosphorus (20 and 30 kg P/ha) in different combinations. To assess the performance of varieties, growth characteristics (shoot length, leaf number, fresh weight and dry weight/plant) were studied at 50, 70 and 90d after sowing. NAR was calculated at 50-70d and 70-90d intervals. The yield parameters (pods/plant, seeds/pod, hecto-litre weight, oil content, seed and oil yield) and quality parameters (acid, iodine and saponification values) were studied at harvest.

Among various combinations of nitrogen and phosphorus $N_{60}P_{30}$ proved best for growth characteristics and NAR but was at par with $N_{60}P_{20}$ for shoot length at 50d, leaf number at 70 and 90d and NAR at both intervals. Yield and quality parameters were best in $N_{60}P_{20}$, although $N_{60}P_{30}$ proved at par with it for seeds/pod, hecto-litre weight, oil content, seed yield and oil yield.

Regarding the performance of varieties, Varuna showed maximum response for all growth parameters at the three stages, NAR at both intervals and yield and quality characteristics. However, shoot length at all stages and leaf number at 70d was maximum in RK-8203 and Pusa Bold respectively. Moreover, KRV-47 showed good keeping quality by virtue of its lowest acid value.

The interaction effect on various growth parameters at different stages, NAR, and yield and quality parameters was variable. However, $N_{90}P_{30}$ X Varuna proved best for most of the parameters including leaf number at 50d and 90d, fresh weight at 50d, dry weight at 50 and 70d, NAR at 70-90d, pods/plant, seed yield and oil yield. For the rest of the parameters, different fertiliser treatments X varieties showed optimum effect.

Experiment 2 (1984-85) was conducted according to simple randomised block design to study the effect of soaking of seeds in 0.0, 0.05, 0.10 and 0.20% aqueous pyridoxine hydrochloride solution for 4h on growth characteristics, NAR, and yield and quality characteristics (as in Experiment 1) of the best performing mustard variety in that experiment, i.e,, Varuna. In addition the effect on root length and leaf NPK contents at 50, 70 and 90d of growth were also studied. Basal dose of 60 kg N, 20 kg P and 30 kg K/ha was applied uniformly.

Soaking the seeds in 0.05% pyridoxine solution gave maximum value for all growth parameters, NAR, leaf NPK contents, and yield and quality characteristics. However, oil content was maximum in 0.10% pyridoxine treatment. Soaking the seeds in water (control) gave minimum values for most parameters.

Experiment 3 (1985-86) was carried out according to factorial randomised block design. The aim of the experiment was to study the effect of pre-sowing seed treatment in graded low doses of pyridoxine solution, three selected combinations of nitrogen and phosphorus and of their interactions on the performance of mustard variety Varuna, assessed in terms of the parameters studied in Experiment 2. Seed treatment comprised

0.0125, 0.025, 0.05 and 0.10% aqueous pyridoxine solution. In addition, there was an unsoaked and a water-soaked controls for comparison. The combinations of fertilisers were $N_{60}P_{20}$, $N_{90}P_{30}$ and $N_{60+30}P_{30}$. The last combination included top-dressing of nitrogen at 30 kg N/ha at 70d of growth.

Seed treatment with 0.025% pyridoxine solution proved optimum for all growth characteristics, NAR, leaf NPK contents and yield and quality characteristics. However, hecto-litre weight was maximum in 0.0125% pyridoxine solution.

Fertiliser treatment, $N_{60}P_{20}$ gave maximum value for growth parameters, including root length, leaf number, fresh weight and dry weight. Whereas, shoot length was maximum in $N_{90}P_{30}$ at all the three stages of growth. The yield and quality characteristics were optimum in $N_{60}P_{20}$, except hecto-litre weight which was maximum in $N_{90}P_{30}$. Top dressing proved ineffective and gave statistically equal values to the optimum treatment for shoot length at 90d, root length at 50 and 70d, leaf P content at 90d and hecto-litre weight.

Regarding interaction effect, 0.025 X $N_{90}P_{30}$, 0.025 X $N_{60}P_{20}$ and 0.0125 X $N_{60}P_{20}$ gave (statistically equal) maximum values for most of the characteristics studied.

Experiment 4 (1985-86), was a factorial randomised field trial conducted with the aimto study the efficacy of soaking of seeds in pyridoxine solution and in three varieties of mustard, namely, PR-18, RK-8203 and Varuna, selected on the basis of their performance in Experiment 1, so as to study their comparative response. Seeds were soaked in 0.0125, 0.025, 0.05 and 0.10% aqueous pyridoxine solution for 4h. In addition, there was unsoaked and water-soaked controls. The parameters were the same as in Experiment 2 and 3.

Seed treatment with 0.0125% pyridoxine solution gave maximum values for all growth parameters, NAR, leaf NPK contents and yield and quality parameters except iodine value which was best in control. However, leaf N content at 50d was maximum in 0.025% pyridoxine solution.

Regarding varieties, Varuna performed best for almost all growth parameters, NAR, leaf NPK contents and yield and quality characteristics except iodine value which was best in PR-18. However, shoot length at 70 and 90d, root length at 50d, leaf number at 70 and 90d and hecto-litre weight were maximum in RK-8203. Varuna and RK-8203 were at par for shoot length at 50d, root length at 70 and 90d, dry weight at 90d, NAR at both intervals, leaf K content at 70d, seed/pod, oil content and iodine and saponification values. PR-18 gave poorest performance.

Among interaction effects, 0.0125 X Varuna and 0.05 X RK-8203 gave (statistically equal) maximum values for most of the growth characteristics, NAR, leaf NPK contents and yield and quality parameters. However, 0.05 X RK-8203 gave significantly maximum value for leaf number at 70 and 90d. Fresh weight at

50 and 90d, NAR at 50-70d, leaf K content at 50d and oil yield were found significantly maximum in 0.0125 X Varuna.

Finally, the present chapter gives the summary of the thesis and is followed by an up-to-date bibliography.

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A P P E N D I X

PREPARATION OF REAGENTS

The reagents for various biochemical determinations were prepared according to the following methods.

1. Reagents for pyridoxine estimation

a. Chloroimide reagent

100 mg of crystalline 2,6-dichloroquinone chloroimide was dissolved in 250 ml of isopropanol. The solution was kept in a glass-stoppered bottle in refrigerator and discarded when pink colour developed.

b. Ammonia-ammonium chloride solution

160 g of ammonium chloride was dissolved in 70 ml of distilled water in which 160 ml of concentrated ammonia water (approximately 27%) was added. The solution was diluted upto 1 l with distilled water.

c. Boric acid solution

5 g of boric acid was dissolved in 100 ml of distilled water.

d. Pyridoxine hydrochloride solution

100 mg of pyridoxine hydrochloride was dissolved in 1 l of distilled water which was kept in an amber coloured bottle in refrigerator.

e. <u>Buffer solution (pH-3)</u>

73 g of sodium phosphate dihydrate and 167 g of citric acid was dissolved in distilled water and diluted upto 1 l.

2. <u>Reagents for NPK determination</u>

a. <u>Nessler's reagent</u>

3.5 g of potassium iodide was dissolved in 100 ml of distilled water in which 4% mecuric chloride solution was added with stirring until a slight red precipitate remained (about 325 ml of the solution was required). Thereafter, 120 g of sodium hydroxide with 250 ml of distilled water was added. The volume was made upto 1 l with distilled water. The mixture was decanted and kept in amber coloured bottle.

b. <u>Molybdic acid reagent (2.5%)</u>

1.25 g of ammonium molybdate was dissolved in 175 ml distilled water in which 75 ml of 10N - sulphuric acid was added.

c. <u>Aminonaphthol sulphonic acid</u>

0.5 g of 1-amino-2-naphthol-4-sulphpnic acid was dissolved in 195 ml of 15% sodium bisulphite solution in which 5 ml of 20% sodium sulphite solution was added. The solution was kept in amber coloured bottle.

3. Reagents for oil analyses

a. Hydrochloric acid (0.5N HCl)

Hydrochloric acid (21.49 ml) was mixed with 478.51 ml of double distilled water (DDW) to get 500 ml of 0.5N HCl.

$$\text{Normality of an acid} = \frac{\%\text{age of acid} \times \text{specific gravity}}{\text{Equivalent weight of acid}} \times 10$$

b. Iodine monochloride solution (ICl)

Iodine (13 g) was dissolved in a mixture of 300 ml of carbon tetrachloride and 700 ml of glacial acetic acid and the resulting solution was divided into solutions A and B. To solution A (20 ml), 15 ml of potassium iodide and 100 ml of DDW was added and titrated against 0.1N sodium thiosulphate solution ($Na_2S_2O_3$), using starch as an indicator. Chlorine gas was passed through solution B until the amount of 0.1N $Na_2S_2O_3$ required for the titration was not more than the double of that needed in solution A.

c. Phenolphthalein solution

Phenolphthalein (10 g) was dissolved in 95% ethanol and the volume was made upto 1 l.

d. Potassium hydroxide solution (0.1N KOH)

Potassium hydroxide (5.6 g) was dissolved in 95% ethanol and the volume was made upto 1 l.

e. Potassium hydroxide solution (0.5N KOH)

Potassium hydroxide (28 g) was dissolved in 95% ethanol and the volume was made upto 1 l.

f. Potassium iodide solution (KI)

Potassium iodide (150 g) was dissolved in DDW and the volume was made upto 1 l.

g. Sodium thiosulphate solution (0.1N $Na_2S_2O_3$)

Sodium thiosulphate (24.8 g) was dissolved in DDW and the volume was made upto 1 l.

h. Solvent mixture

Ethanol (95%) was mixed with diethyl ether in 1:1 ratio. This mixture of solvents was neutralised just before use by means of 0.1N KOH solution in the presence of phenolphthalein solution as an indicator.

i. Starch solution

Soluble starch (1 g) was dissolved in 100 ml of boiling DDW.